JUN 22'45M

The INSTITUTION of PRODUCTION ENGINEERS

JOURNAL

(*May* 1944, *Vol. XXIII, No. 5, Ed. A*)

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RUBBER AS AN ENGINEERING MATERIAL
by J. S. Moyal

THE TRAINING AND PROSPECTS OF THE YOUNG PRODUCTION ENGINEER
by F. P. Liebert, Grad.I.P.E.

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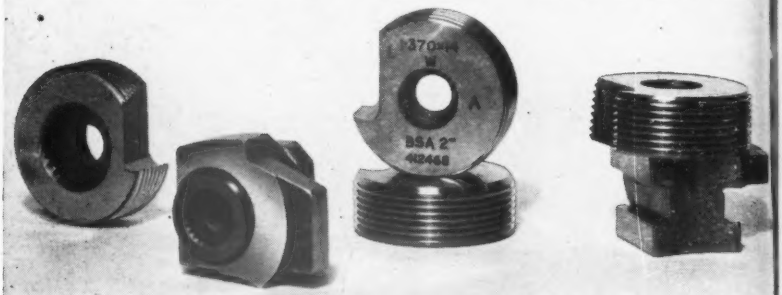

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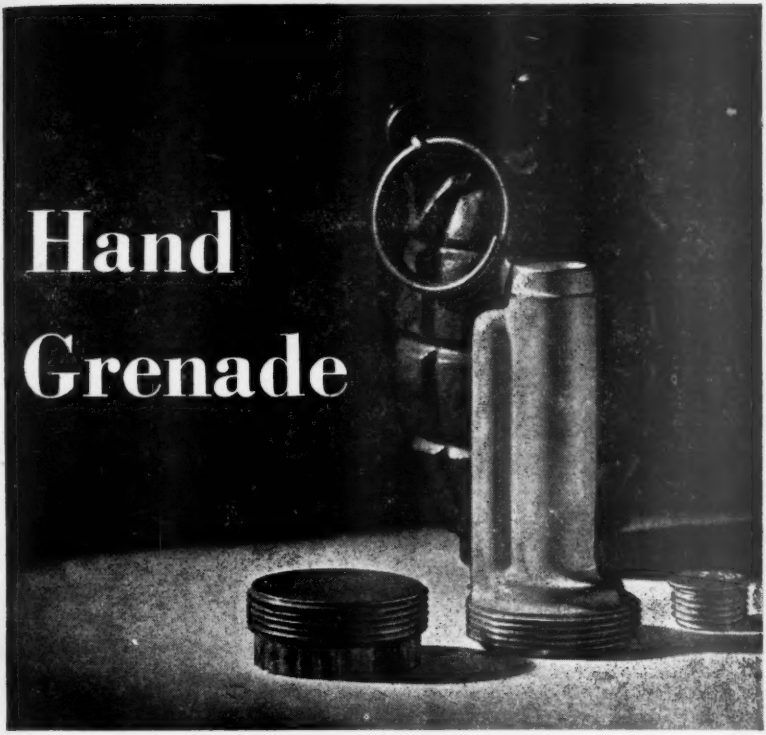

VITAL PARTS DIE CAST IN ZINC ALLOY

Next to the rifle, the soldier's best known weapon is the hand grenade. In the typical grenade shown above, zinc alloy die castings constitute the most vital parts, including the fuse.*

The use of zinc alloy for these parts enables the grenades to be produced at an incomparably higher speed than was possible in the last war, and with a great saving of metal and man-hours.

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* * *

No. 2 in a series of advertisements issued by the Zinc Alloy Die Casters Association, an organisation formed by the industry to improve the technique of zinc alloy die casting and to promote a fuller appreciation of the properties and applications of the castings.

*Shown slightly reduced, these parts were pressure die cast in zinc alloy conforming to British Standard 1004

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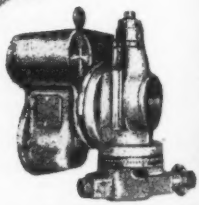

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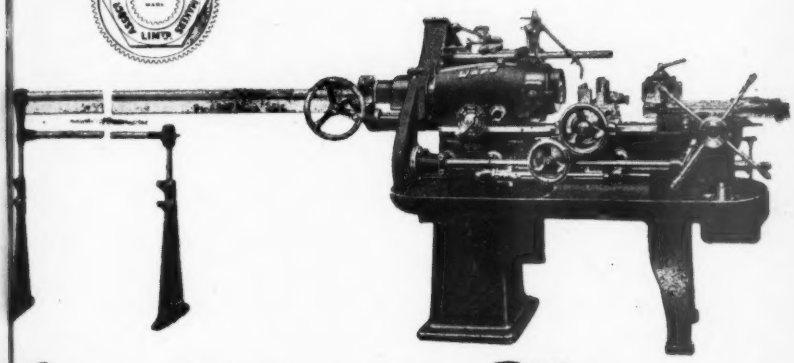

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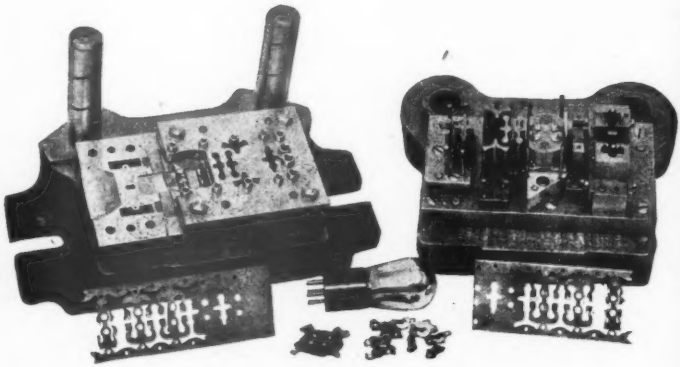

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Coo! mum!

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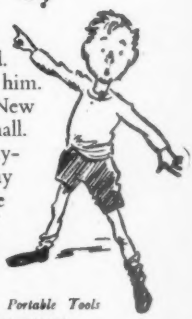

In the bad old days men who had to bore holes and screw screws in awkward spots used to come home looking like sticks of barley sugar. Their arms and legs got mixed up and often when they tried to give young Bert a well-earned clip on the ear, " A Present from Scarboro' " fell off the mantelpiece instead. Mum didn't like it. Nor did Dad. Nor young Bert neither when Dad finally caught up with him. Then came the age of Desoutter, sometimes known as the New Dawn or Millennium. Now at last small power tools *were* small. A man could hold a Desoutter in one hand and make it work anywhere that a mouse could squeeze. Many a good wife to-day keeps a bust of *Desoutter The Good* on her mantelpiece. She doesn't care much about the blessings he has brought to Industry. She just appreciates that nowadays her old man comes home the same shape as he started out.

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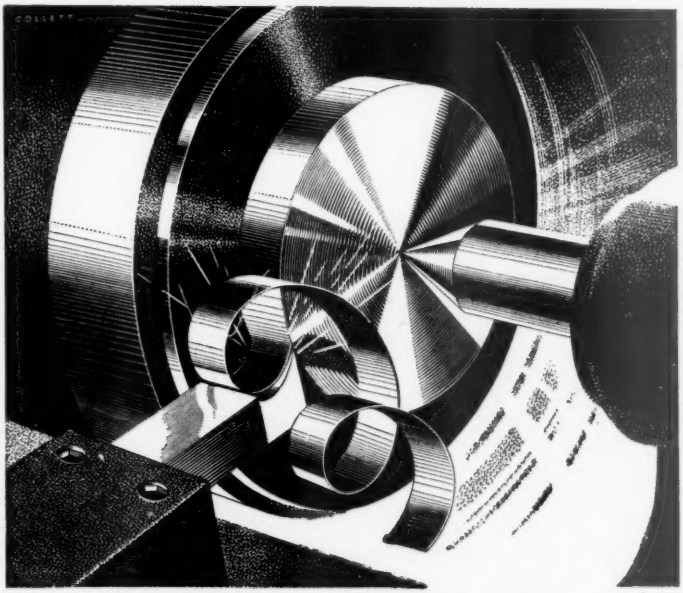

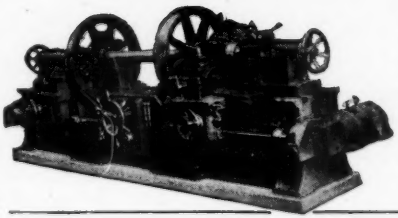

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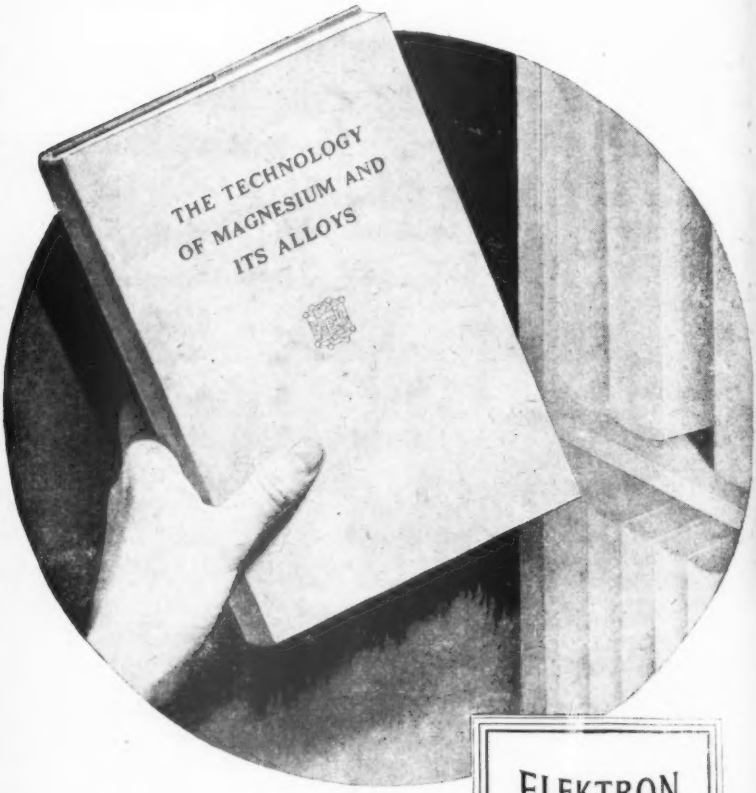

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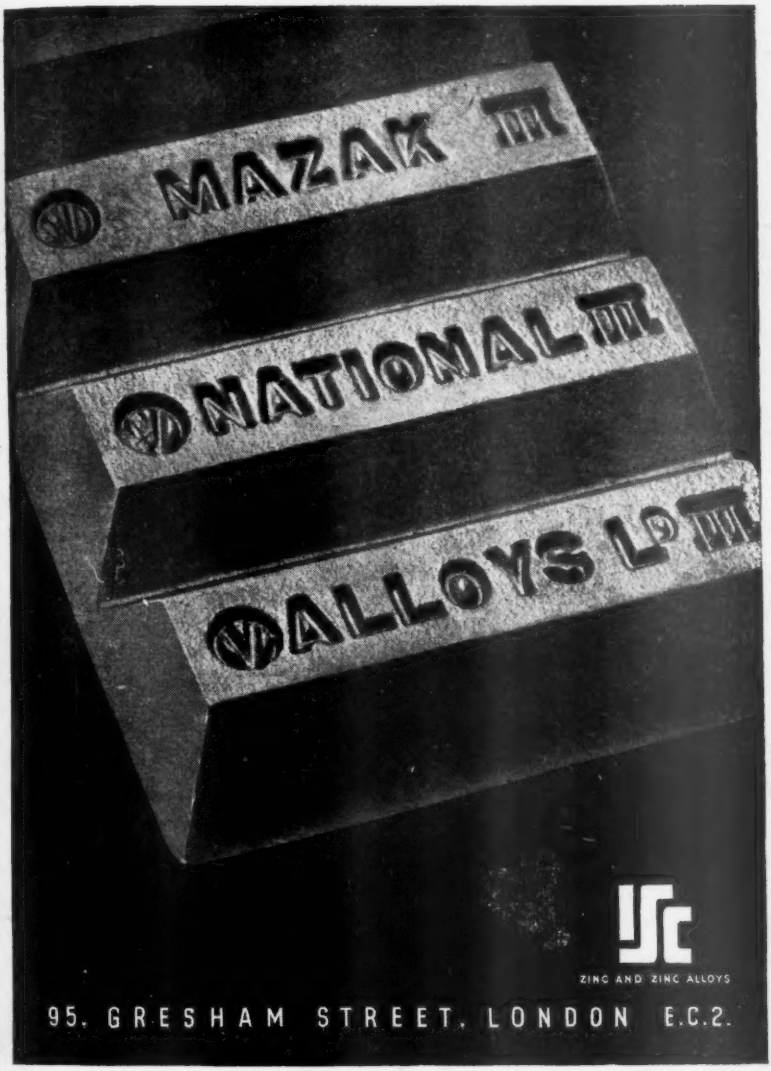
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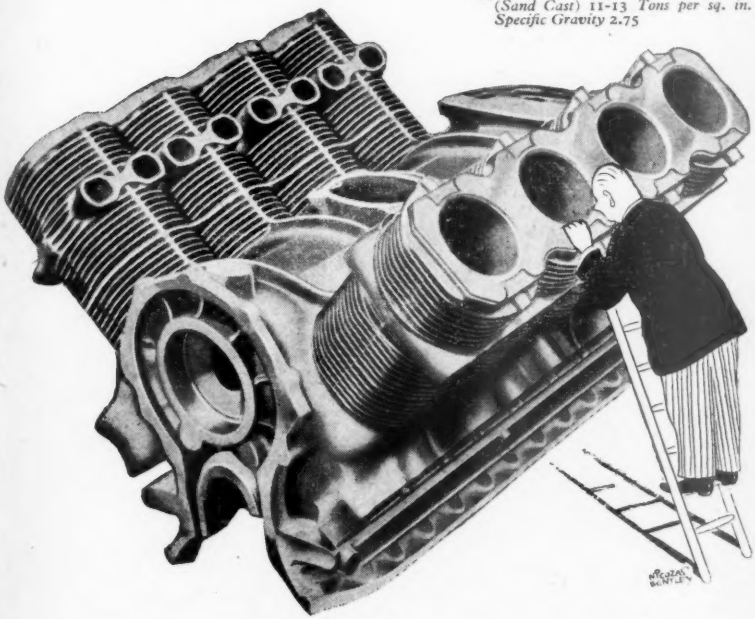

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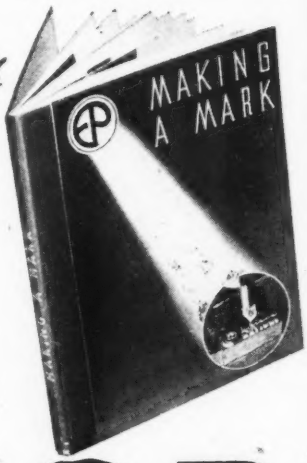

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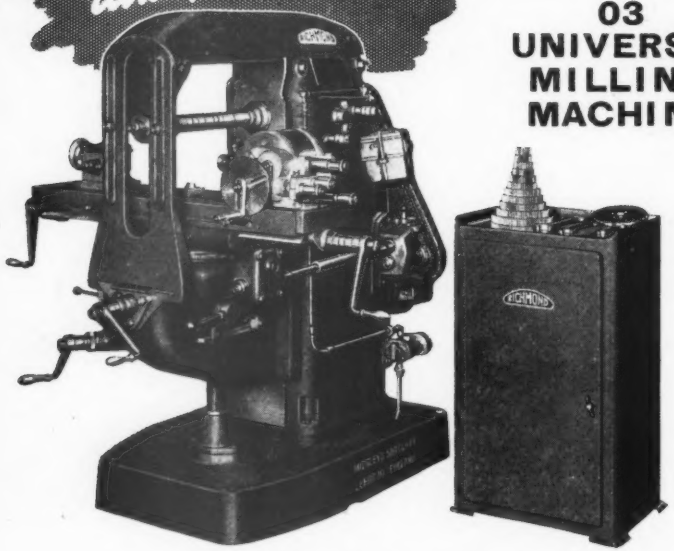

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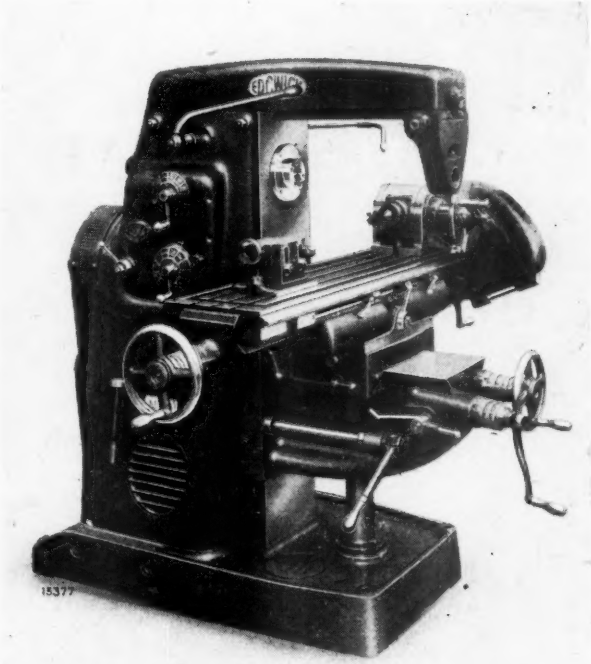

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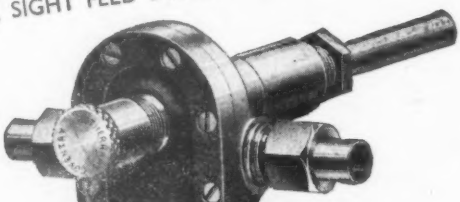

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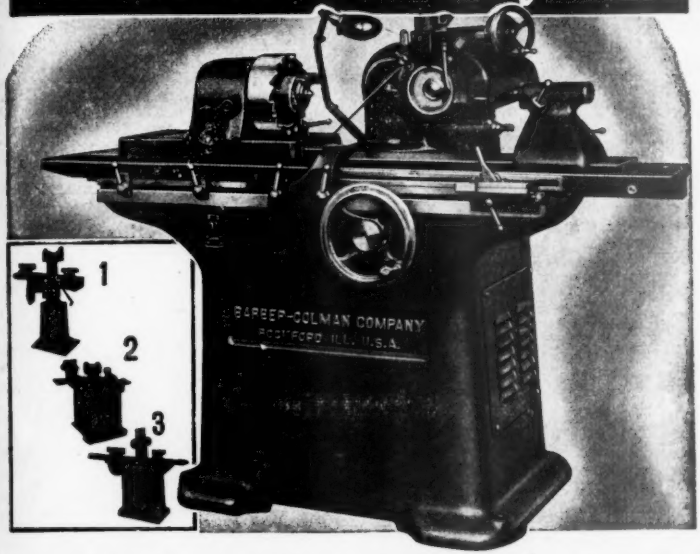

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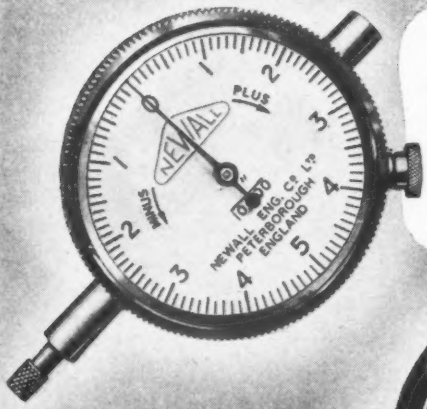
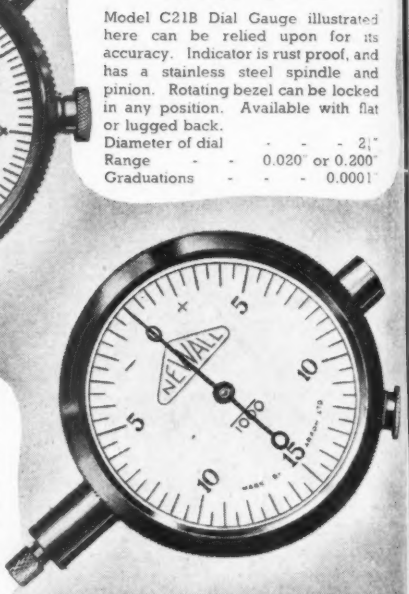


Model C21B

Model C21B Dial Gauge illustrated here can be relied upon for its accuracy. Indicator is rust proof, and has a stainless steel spindle and pinion. Rotating bezel can be locked in any position. Available with flat or lugged back.

Diameter of dial	2½"
Range	0.020" or 0.200"
Graduations	0.0001"



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1943-44

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INSTITUTION NOTES

May 1944

June Meetings.

2nd London Section. A Meeting will be held at the Institution of Civil Engineers, Gt. George Street, S.W.1., at 7-0 p.m., when Mr. H. Grafton will lecture on "Aero Tool Metrology."

June Committee Meetings, etc.

9th A meeting of the Co-ordinating Committee at Institution Headquarters at 11-0 a.m.

12th Research Finance Committee, at Loughborough at 10-30 a.m.

16th London Section Committee Meeting, Institution of Civil Engineers, Gt. George Street, S.W.1. at 9-30 a.m.

16th Finance and General Purposes Committee at the Institution of Civil Engineers at 1-0 p.m.

23rd The Council of the Institution at the Institution of Civil Engineers, Gt. George Street, S.W.1. at 11-30 a.m.

27th Education Committee Meeting at Queens Hotel, Birmingham, at 10-0 a.m.

27th Membership Committee Meeting at Queens Hotel, Birmingham, at 12-30 p.m.

The Technical and Publications Committee meets at Institution Headquarters every Wednesday at 5-30 p.m.

Personal Column.

We have pleasure in announcing that Mr. J. E. Blackshaw has been elected to the Board of Directors of Messrs G. D. Peters & Co. Ltd., Slough. Mr. Blackshaw was President of the London Section from 1940 to 1942.

Mr. F. B. White has left the employ of Messrs. Hoover Ltd., to take up an appointment as Chief Engineer, Screw Division with Messrs. Guest, Keen & Nettlefolds Ltd. Mr. White was until recently a member of the London Section Committee and the Technical and Publications Committee.

Technical and Publications Committee.

During recent weeks several changes have taken place on the composition of the Technical and Publications Committee. Mr. R. Kirchner, who has guided this Committee so ably for the past 18 months, has resigned from the Chairmanship. Whilst this decision is very much regretted it is pleasing to state that he will remain a member of the Committee, and thereby continue to give the Committee the benefit of his knowledge and experience.

The duties of Chairman have now been taken over by Mr. A. W. McLeod, and his specialised knowledge of editing technical publications will be of considerable value to the Committee. The new chairman will be supported by Mr. A. A. Francis, who has been elected Vice-Chairman, the latter having been a member of this Committee from its inception.

Due to the increasing calls upon his time, Mr. B. H. Dyson has reluctantly tendered his resignation. Mr. Dyson, like Mr. Francis, was one of the few remaining members who comprised the original Committee, and his assistance will be greatly missed.

Halifax Section Inaugural Meeting.

The inaugural meeting of the Halifax Section was held at the White Swan Hotel, on Saturday, 22nd April, 1944. The function comprised a luncheon attended by the Mayor of Halifax ; Colonel Mustill (President of the Yorkshire Section of the Institution) ; Mr. B. R. Heaseman (Halifax Technical College) ; Dr. Ward (Huddersfield Technical College) ; Mr. Mark Taylor ; Dr. Schlesinger ; Mr. Daniels ; Mr. J. D. Scaife ; Dr. Fenelon (Secretary of the Institution) and many other prominent personalities, the company numbering about 60.

The President, Mr. W. P. Eastwood, M.I.P.E., explained that the section covered the area of Huddersfield, Brighouse, Sowerby Bridge, Hebden Bridge, and part of Todmorden. Meetings would be held alternatively in Halifax and Huddersfield.

The hope was expressed that engineering employers locally would take an interest in the work of the Institution and its Research Department, both of which render valuable service to the engineering trade, and in particular help it to meet post-war competition in a variety of ways.

In the afternoon, a paper was read before a large company by Dr. Schlesinger on "A Comparison of Methods of Training Production Engineers in America, Germany, and England." The paper was accompanied by lantern slides.

Derby Sub-Section.

Subject to the approval of Council, the Nottingham Section Committee propose to form a Sub-Section in Derby. A provisional Committee has been elected and it is hoped that the Inaugural Meeting will be held at the commencement of next Session.

Wolverhampton Graduate Section.

The Inaugural Meeting of the Wolverhampton Graduate Section was held on Wednesday, 24th May, at Wolverhampton and Staffordshire Technical College. His Worship the Mayor of Wolverhampton, Mr. F. S. Thompson presided. An inaugural address on "The Training of the Production Engineer" was delivered by Dr. E. W. Fisher, O.B.E. Other speakers included Mr. E. W. Hancock, President of the Wolverhampton Section and Dr. K. G. Fenelon, General Secretary. The meeting was well attended, some 250 people being present.

RUBBER AS AN ENGINEERING MATERIAL

Paper presented to the Institution, Leicester Section, on 15th October, 1943, by J. S. Moyal

The Rubber-Like State.

THIS paper is concerned chiefly with the properties of rubber and rubber-like substances considered as engineering materials. Before going on to those properties which are of interest to the design engineer, I shall say a few words about the theory of rubber.

The peculiar properties of rubber and rubber-like materials may be considered as constituting a separate state of matter. Many substances can pass through several states:—

1. Vapour.
2. Viscous liquid.
3. Rubber-like highly elastic.
4. Glass-like, amorphous solid.
5. Crystalline solid.

Natural rubber, for example, can be found in all these states,* according to its temperature, and the stresses imposed upon it. This applies equally well to all the synthetic rubbers and to gutta-percha for example, which exhibits rubber-like properties at temperatures above 60°C.

What I wish to emphasise is that the special high elasticity which forms the most interesting characteristic of rubber, is not connected with a particular chemical constitution, but has the character of a physical state, and can occur with bodies having very different chemical compositions.

There is no completely satisfactory theory of the rubber-like state as yet. The latest ideas on the subject are based on the theory that the molecules of rubber-like bodies form into long chains. Natural rubber, for example, it has been estimated, comprises of 5,000 isoprene units per chain molecule

Application of the term " molecule " to such a chain has been strongly contested, and another word for it is " micelle." These chains are supposed to be connected at their beginnings and ends to other chains. The atoms in each chain can rotate about atomic bonds, and it is supposed that they rotate in random fashion, so that the chain has a complex kinked appearance.

* Except in the vapour state, as it usually undergoes chemical decomposition at high temperatures.

It is this random motion of the atoms in the atomic chain which is used to explain the properties of rubber, and especially its elasticity. If the rubber is stretched, the chains tend to be straightened out in the direction of the stretching, while the random motions tend, on the average, to resist the stretch. A mathematical theory has been developed on the basis of these assumptions, and is generally referred to as a kinetic theory of rubber from its similarity to the kinetic theory of gases.*

However, I shall not go any further into this subject. The one point to remember is that the peculiar properties of the rubber-like state are not connected with any particular chemical constitution, as is evident from the range of synthetic rubbers which are being produced now, and which are of a very different nature chemically. This has great importance from the engineer's point of view, since it opens up the possibility of the future development of materials which possess the highly elastic properties of rubber, and, in addition, various special properties which are of particular interest in certain applications.

In other words, the development of synthetic rubber-like materials is parallel to the developments of new alloys to meet special demands. For example, natural rubber is attacked by oil, while some of the synthetic rubbers, such as Neoprene, are impervious to the action of oil. Thus, by using Neoprene, one can take advantage of the properties of rubber by introducing it in parts of machines which are bathed in oil. This was impossible with natural rubber, if one expected any length of life.

Possibilities Introduced by the Rubber-to-Metal Weld Process.

The possibilities of rubber as an engineering material have been enormously extended by the process of welding, or bonding, as it is often called, rubber to metal.

By this process, the rubber and the metal are welded together so strongly that usually the strength of the weld is greater than the strength of the rubber itself.

There are several methods of obtaining this welding. The best known so far is the plating process, which can be used with a great variety of metals. This consists of brass-plating the surface of the metal, and then applying unvulcanised rubber (I shall use the word rubber from now on to denote both natural and synthetic rubbers), using special moulds to give it the required shape. The rubber is then vulcanised with the application of heat and pressure, the vulcanisation process causing the rubber to adhere firmly to the plated surface. The cause for this adhesion is not really

*L. R. G. Treloar, Reports on Progress in Physics, v. 9 (1942-43) pp. 113-136

completely known, but it must be supposed that it is connected with a chemical reaction probably between the sulphur used in the vulcanising process, and the copper in the brass layer.

Special precautions have to be taken both as to the nature of the plating, and the cleanliness of the surface, etc. The strength of bonds obtained in this manner varies chiefly with the nature of the rubber. For example, with natural rubber, it may vary from say, 350 lbs. per square inch for the softer rubbers, up to 1200 lbs. per square inch with some of the harder qualities. These figures represent breaking strengths, and must not be used in practice; practical values are between 30 and 70 lb. per square inch. The reason for this very large margin between normal stresses and breaking stresses, is connected with a phenomenon peculiar to rubber, which has been called "Static Fatigue." I shall deal with it later on.

Many of the advantages conferred by the rubber-to-metal welding process are, of course, obvious. One of the greatest applications of rubber in engineering, is as a springing material to be used for insulation against vibrations, or for absorbing shocks. With this welding process, rubber springs of the most complicated shapes can be easily constructed.

One of the great advantages of the rubber spring over the metal one, is that it can be stressed in any direction; stresses can be applied at the same time in shear, compression, tension and torsion, and it will act as a spring simultaneously for all these stresses, while with a metal spring, a single unit will only be stressed in one direction.

Another advantage of the use of rubber, is that it has inherent damping properties. Vibrations caused by shocks will be quickly damped out in rubber, while with steel springs, one is forced to introduce dashpots, etc., to produce damping.

A further advantage of rubber when used for insulation of mechanical vibration, is that it acts at the same time as an acoustical insulator, while steel springs, even if they do insulate against mechanical vibrations, transmit vibrations of higher frequency so that if acoustical insulation is required, additional means to effect this are necessary.

I have used the word "spring" here in a very general sense; for example, one of the most invaluable applications of rubber is in flexible shaft couplings, where the rubber is connected as a torsion spring. These couplings are used to take up malalignment between shafts; to insulate a machine from the torsional vibrations of the engine which is driving it; to have a cushioning anti-shock effect in clutches; and in many other applications.

Another useful application is the torsional vibration damper, which is used to absorb the energy of torsional vibrations in engines,

thus preventing crankshaft breakages. The torsional vibration damper consists of three parts, a coupling flange, a rubber torsional spring, and a small flywheel bonded to the rubber. The normal type of mechanical damper contains up to 35 parts all requiring adjustments, etc., while the rubber damper requires no adjustments.

The direct use of rubber as a spring for vibration insulation is well known, and takes two forms : springs used to insulate objects

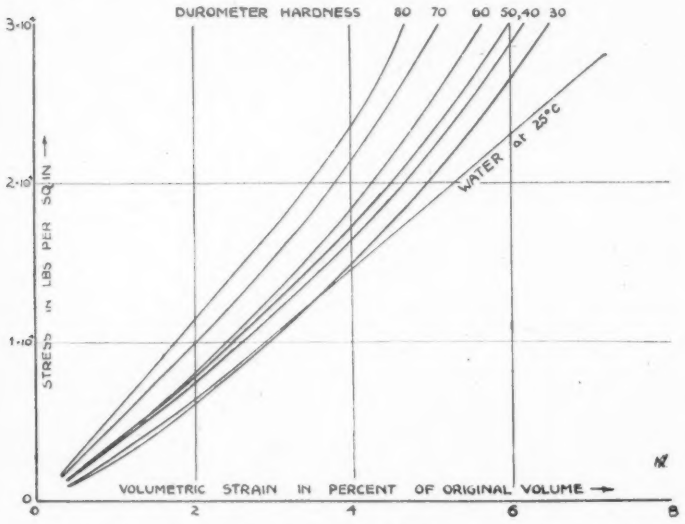

Fig. 1.—Volumetric stress/strain curves in a few representative natural rubber compounds, as compared to water at 25°C.

such as instruments from vibrations of the base to which they are attached, and springs used to prevent the transmission of vibration from motors, engines, pumps, etc., to their supporting members. Rubber is used in the latter case, for example, in the so called floating power systems of motor car suspensions, and in the suspensions of aero engines.

Other applications such as for buffer springs, etc., are obvious to the mind of the engineer, but besides the use of rubber as a spring, welding introduces the possibility of numerous other applications which will suggest themselves to engineers as time goes on. Hydraulic engineers, for example, should find great possibilities there. Bonded parts have been used already as pipe couplings, valve

seals, etc. Electrical engineers have, of course, been familiar with the use of rubber for a long time now as an electrical insulator. Here again, the bonding process opens up new possibilities. It has been applied, for example, for antenna bases and plugs and sockets.

Elastic Characteristics of Rubber under Static Conditions.

Rubber resembles a liquid in that it is highly deformable, but not compressible in volume (c.f. Fig. 1). It is unlike a liquid, however, in the fact that the forces that resist the deformation

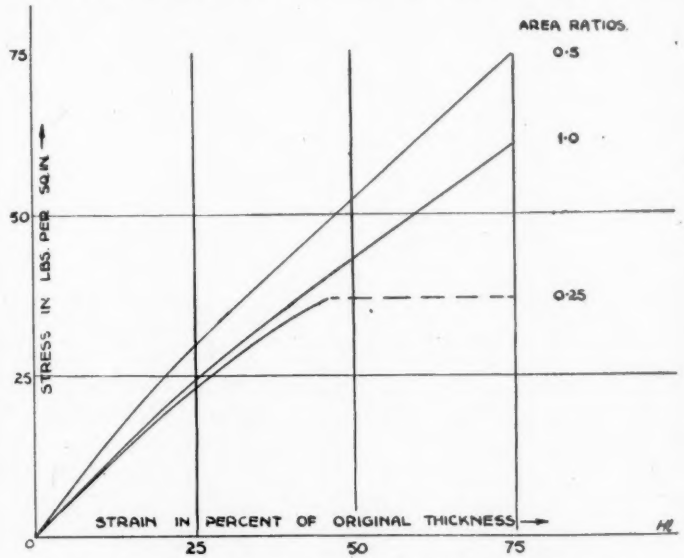

Fig. 2.—Shoar stress/strain curves in a typical soft natural rubber compound, for area ratios from 0.25 to 1.00.

are chiefly elastic in nature, i.e., they are functions of the displacement. In fact, there is also a component in the nature of a viscous force, as in liquids, i.e., which depends on the velocity on the deformation, and vanishes at infinitely slow rates. However, this component is small as compared to the elastic component. We shall go further into the nature of the viscous force later on when we discuss the properties of rubber under dynamic conditions.

We shall consider first what we may call the static case, where the loads are applied to the rubber slowly. A welded rubber

spring can be loaded in three ways: in shear, where the bonded surfaces move parallel to each other, in compression, and in tension. It is found that for shear deformation, the stress/strain curve is very nearly linear up to quite large deformations, i.e., strains of 50% or more. Furthermore, for a given rubber quality, the slope of the stress/strain curve, i.e. the shear or rigidity elastic modulus, is very nearly constant, and independent of the shape of the rubber. (c.f. Fig. 2). This is an important characteristic, which does not apply to tension or compression. I may mention here that this rigidity modulus varies from about 40 lbs. per square inch to 250 lbs. per square inch for the rubber qualities usually employed in welded articles. However, there is no difficulty in welding to even harder rubber, having a higher modulus.

The stress/strain curves for compression and tension are definitely not linear, and depend on the shape of the rubber unit as well as on the rubber quality.

An approximate method of characterising this dependence on shape was introduced by W. C. Keys* and makes use of the ratio of the load area to the free or "bulge" area, called "area ratio" or "shape factor." The load area is half of the area to which the rubber is bonded, and therefore restrained from moving. The free or bulge area is the part of the surface of the unit where the rubber is free to move when the load is applied. Series of stress/strain curves can be drawn for each rubber quality, and for various values of the area ratio (c.f. Fig. 3). It is found that for values of this ratio from 0.25 to about 2.5, the stress/strain curve is approximately independent of the shape. This applies to units having parallel bonded surfaces, where the ratio of the maximum to the minimum linear dimensions of the bonded surfaces is not greater than 10. It will be obvious that the curves will be steeper, i.e. the rubber will be stiffer in compression when the area ratio is high, since rubber is incompressible in bulk, and the area over which it it can deform is proportionately reduced.

In fact, if we consider an infinitesimal volume of rubber and a very small deformation, we should expect Young's modulus to be almost exactly three times the rigidity modulus, since the Poisson ratio for a body which is incompressible in bulk must be $\frac{1}{2}$. We have the following well-known relations denoting by K the bulk modulus, by S Poisson's ratio, by E. Young's modulus, and by N the rigidity modulus

$$K = \frac{E}{3\,(1-2S)}$$

For $S = \frac{1}{2}$, K becomes infinite, i.e. the body is incompressible in bulk.

* W. C. Keys, "Rubber Springs," *Mechanical Engineering*, May, 1937.

We then have

$$E = 2N\ (1 + S) = 3N.$$

This theory is justified experimentally by the fact that if a rubber slab is compressed between two plates without being bonded to them, and if these plates are lubricated with soap, it is found that at the beginning of the stress/strain curve, the slope of the curve

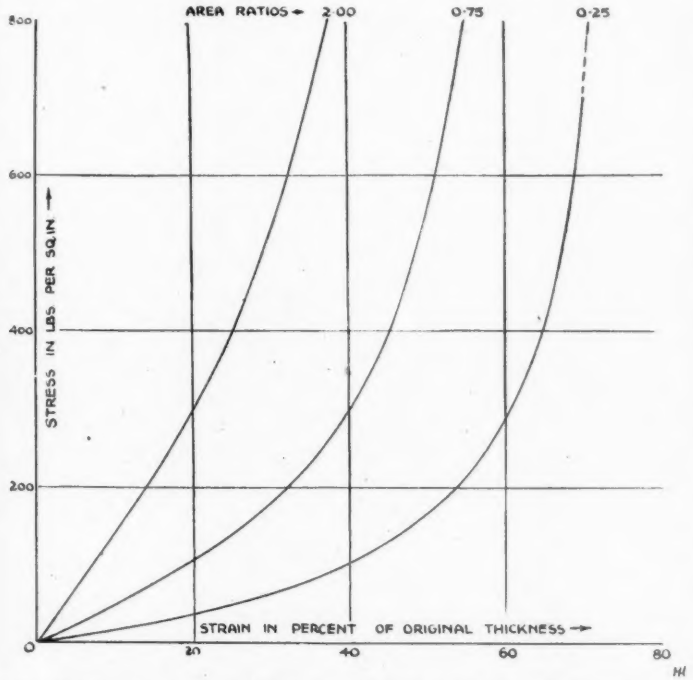

Fig. 3.—Compression stress/strain curve in a typical soft natural compound, for area ratios from 0.25 to 2.00.

is about three times that of the shear curve for the same rubber quality. Actually, on bonded units, it is the fact that the bonding restrains part of the rubber from moving that stiffens up the rubber in compression.

All these facts are of great value to the designer, as they permit the construction of rubber springs which may be very stiff along the compression axis, while they remain very flexible along the shear

axis. A good example is an aero engine mounting, which has to bear the weight of the engine along its compression axis, while it must insulate the air frame from engine or propeller vibrations along its shear axis. This is effected by putting in interleaves between the two lateral plates of the rubber sandwich used for this purpose. These interleaves have the effect of increasing the ratio of load area to bulge area, and consequently of increasing the stiffness in compression without increasing it appreciably in shear. Thus the rubber sandwich retains its shear flexibility, while at the same tine it gives very little under the gravity load, and consequently will take a heavy load with quite a small volume of rubber.

With regard to the tension characteristics, they are perhaps of less interest to the engineer, as the use of rubber in tension is not considered good practice, owing to the fact that when rubber is in tension exposed surfaces are very liable to injury because any cracks or scratches tend to spread rapidly. It is advisable when it is wished to use rubber in tension, to protect free rubber surfaces from injury.

Creep and Elastic After Effects.

With regard to the static stress/strain or load/deflection curves which have been mentioned above, there is one point to be kept in mind—these can never be very accurate, owing to the phenomenon of creep which rubber exhibits under load. Rubber will take the greatest part of its deflection as soon as the load is applied. It will then go on deflecting, fairly rapidly at first, then at a slower rate, the additional deflection getting smaller and smaller, practically indefinitely. Curves in Fig. 4*, which are on a logarithmic scale, and show creep versus time; most of these creep curves are straight lines, showing that the logarithm of the creep is proportional to the logarithm of the time. Owing to this phenomenon of creep, stress/strain curves have a different shape according to the rate of loading. This introduces a margin of uncertainty when it is wished to compare static measurements, especially when obtained in different laboratories. It is for this reason that we have been trying to specify our rubber qualities by dynamic measurements under vibrating conditions, which cannot be affected by the rate of loading.

I may mention here that the phenomenon of creep is only partly due to plastic deformation, because there generally is practically complete recovery of the rubber when the load is taken off, if it is given sufficient time. This is known as the elastic after-effect.†

* Taken from a paper by F. L. Haushalter, "The Rubber Age," September 1939, p. 219.

† This is not the case, however, with some of the synthetic mixes, which exhibit marked plastic deformation under sustained load.

The Dynamic Characteristics of Rubber.

As mentioned before, rubber is very largely used for insulation against vibrations, and for vibration or shock absorption, so that characteristics of rubber under conditions of vibration are of peculiar

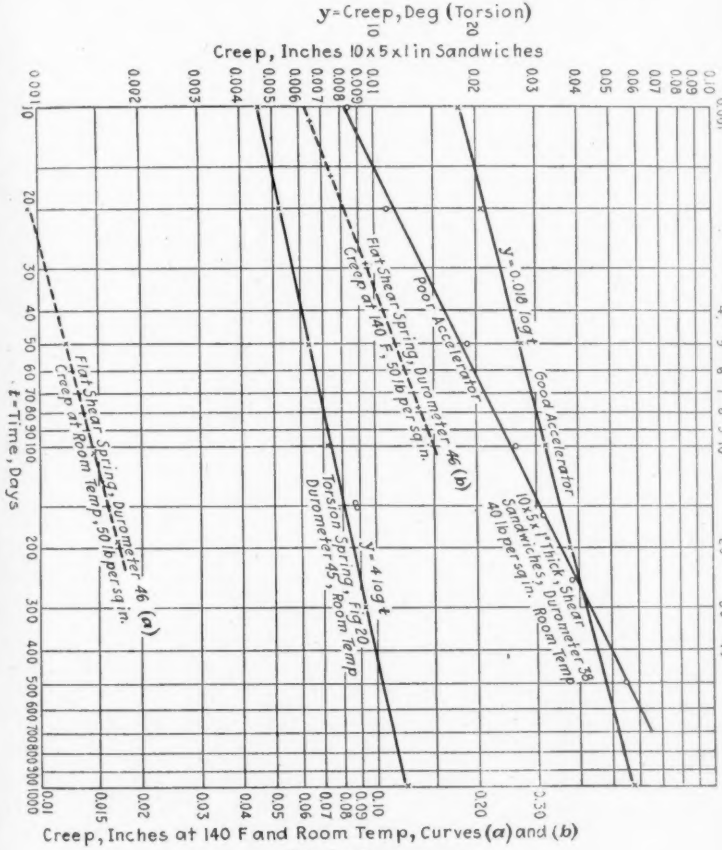
y=Creep, Deg (Torsion)
Creep, Inches 10x5x1 in Sandwiches
Scale for Curve (a)
t-Time, Days
Creep, Inches at 140 F and Room Temp, Curves (a) and (b)
Flat Shear Spring, Durometer 46 (a)
Creep at Room Temp, 50 lb per sq in.
Flat Shear Spring, Durometer 46 (b)
Creep at 140 F, 50 lb per sq in.
Poor Accelerator
y=0.018 log t
Good Accelerator
10x5x1" Thick, Shear Sandwiches, Durometer 38
40 lb per sq in.
Room Temp
Torsion Spring Durometer 45, Room Temp
Fig 20
y=4 log t

Fig. 4.—Creep curves.

importance. Furthermore, the elastic characteristics can be measured more accurately under dynamic than under static conditions.

There has, therefore, been a tendency lately to develop methods of testing under actual vibrating conditions. Figure 7 shows one laboratory device used for dynamic measurements on welded test pieces, and also on small welded anti-vibration mountings.

In order to explain this method of testing, I will say a few words about the theory of the simple vibrating system with one degree of freedom. Consider, for example, a simple shear rubber sandwich fixed at one end and with a mass suspended from the other (c.f. Fig. 5). Suppose a harmonic force $p = P \cos = (2 \pi f t)$ is applied

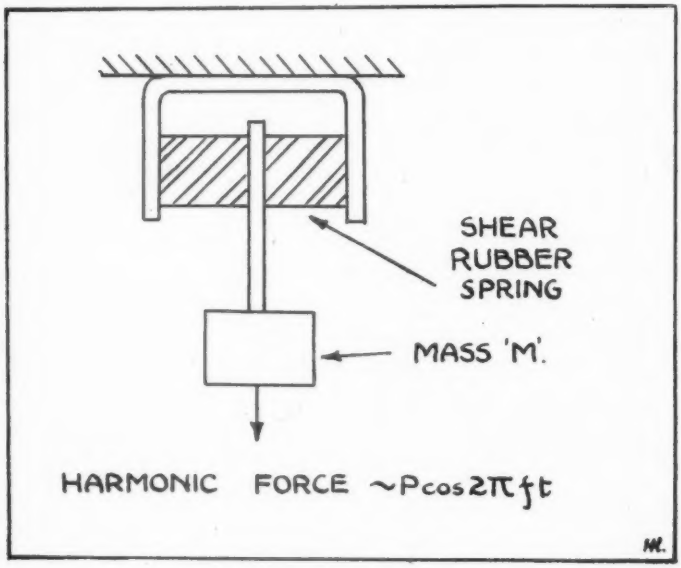

Fig. 5.—Simple vibrating system.

to the mass, where P = amplitude of the pulsating force in lbs. f = the frequency of the applied force in cycles per second. (c.p..s.)

If we apply the laws of mechanics to this system, we see that the applied force is opposed by the sum of the inertia force, due to the vibration of the mass, the elastic shear force due to the deformation of the rubber and the damping force due to the viscous flow of the rubber. For small amplitudes, the elastic shear force is proportional to the displacement, the coefficient of proportionality being the spring rate of the rubber sandwich. The damping force can be

supposed proportional to the velocity, and we call its coefficient of proportionality the damping coefficient.

We have then: inertia force=mass x acceleration= $M\ a$; elastic force = spring rate $\times$ displacement = $K\ x$; damping force = damping coefficient $\times$ velocity = $R\ v$.

Hence

$$M\ a + K\ x + R\ v = P\ cos\ 2\ \pi\ f\ t \tag{1}$$

This is the equation of motion for this simple vibrating system, and it is well known that the motion obtained settles after a time to a simple harmonic motion, with the same frequency as the applied force.

i.e. $x = X\ cos\ (2\ \pi\ f\ t - \phi)$

where X = the amplitude of the forced vibration

ϕ = the phase of the forced vibration.

We shall not go fully into the solution of this equation. It is sufficient to say that X passes through a maximum when the frequency is varied. This maximum occurs for the frequency.

$$f_n = \frac{1}{2\pi}\sqrt{\frac{K}{M}} \tag{2}$$

f_n is called the "resonant frequency," or "natural frequency" of the system.

From the above equation, we see that the resonant frequencies depend not on the characteristics of the force, but only on the spring rate and mass. The amplitude obtained at resonance, i.e. maximum amplitude for a force of given amplitude is

$$X_n = \frac{P}{2\pi R f_n} \tag{3}$$

Thus the amplitude at resonance is inversely proportional to the damping coefficient and to the natural frequency. In fact, the expression above shows that once we have determined these two values, i.e., the resonant frequency, and the amplitude at resonance and if, moreover, the mass M and amplitude of the pulsating force P are known, we can then work backwards to determine the spring rate K, and the damping coefficient R, under dynamic conditions.

Now, if we were using a steel spring instead of the rubber spring, the spring rate thus determined would be equal to the one determined by the static measurements, i.e.,

$$K_o = \frac{P_o}{X_o} \tag{4}$$

P_o being a static load, and X_o the static deflection under this load.

However, this is not the case for rubber. It has been found experimentally, that the spring rate, as determined above through vibration characteristics, is from 1.2 to 7.5 times as great as the spring rate determined from static measurements.

The damping coefficient is also of great interest to the engineer, since it is through the existence of damping that rubber actually absorbs mechanical energy, which is then dissipated in the form of heat. The energy thus absorbed per second at resonance is $4\pi^2 f_n^2 RX_n^2$.

Of course, one can work backwards from the values of the spring rate to obtain the shear modulus under dynamic conditions. From a well known expression, the spring rate for a sandwich with parallel faces, having a thickness h and area A, will be

$$K = \frac{NA}{h} \tag{5}$$

where N is the shear modulus in lbs./square inch.

It is possible to define what we may call a shear viscosity modulus which is also characteristic of the rubber. It is shown that the damping coefficient will have an expression similar to that of the spring rate.*

$$R = \frac{VA}{h} \tag{6}$$

where V is the viscosity modulus in lb. seconds per square inch. The shear modulus can be considered for practical purposes as depending only on the quality of the rubber, and in the same manner, the viscosity modulus *at a given frequency* depends only on the rubber quality.

However, it is found that the viscosity modulus is not independent of the frequency, but is roughly inversely proportional to it. This phenomenon is quite common with most solids : the energy absorbed per cycle is roughly constant. The vibrating energy absorbed per second is then proportional to the frequency. It is generally accepted that energy absorption in elastic solids is due to the phenomenon of elastic hysteresis.†

If we take the ratio

$$d = \frac{2\pi^2 V f_n}{N} \tag{7}$$

we obtain what is usually called the "logarithmic decrement." of the rubber, which is fairly constant, and has values of from 0.1 to 0.6 for various rubber qualities.

As mentioned above, metals and other crystalline solids also exhibit damping. However, their viscosity modulus is of a much smaller order than that of rubber, and consequently their capacity to convert energy into heat and to damp vibration is comparatively negligible.

I may mention here that in shock absorbers, an important

* A. L. Kimball, *A.S.M.E.Trans.*, 51 (1) 1929 pp. 227-236.

† A. L. Kimball, loc. cit.

quality is the damping of free vibrations. If a rubber spring is given an impulse, we can characterise this damping by the natural logarithm of the ratio of two successive amplitudes X_n/X_{n+1} of the free vibration. It is easily shown that this is equal to the logarithmic decrement defined previously at (7)

$$d = \frac{2\pi^2 V f_n}{N} = log_e \frac{X_n}{X_{n+1}} \tag{8}$$

f_n being the natural frequency as defined in expression (2).

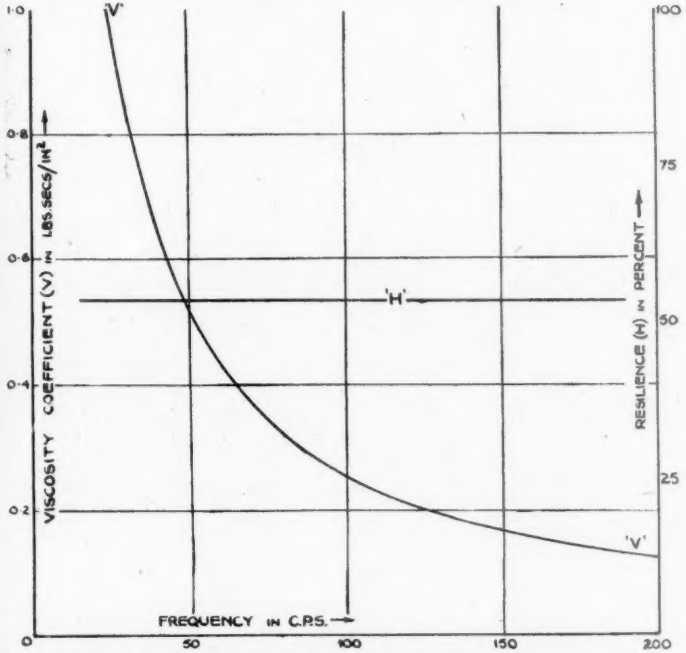

Fig. 6.—Viscosity modulus and resilience as functions of frequency for a hard synthetic rubber compound with a dynamic shear modulus of 794 lbs./sq. inch.

In the rubber industry, it is usual to characterise damping by means of a quantity called "resilience," which is expressed in % and is equal to 100 times the ratio of two successive amplitudes for a free vibration. It will therefore be seen from (8) that resilience is connected with logarithmic decrement by the following expression (denoting resilience by H).

$$H = 100\,\frac{X_{n+1}}{X_n} = 100e^{-d} \tag{9}$$

Fig. 6 shows viscosity modulus resilience plotted against frequency for various rubber qualities. It will be generally found to vary for normal qualities, both synthetic and natural, from 50% to 90%.

The method of measurement shown in Fig. 7, is based on the theory above. The motor shown has a rotating arm with unbalanced weights which cause a vertical up and down pulsating or

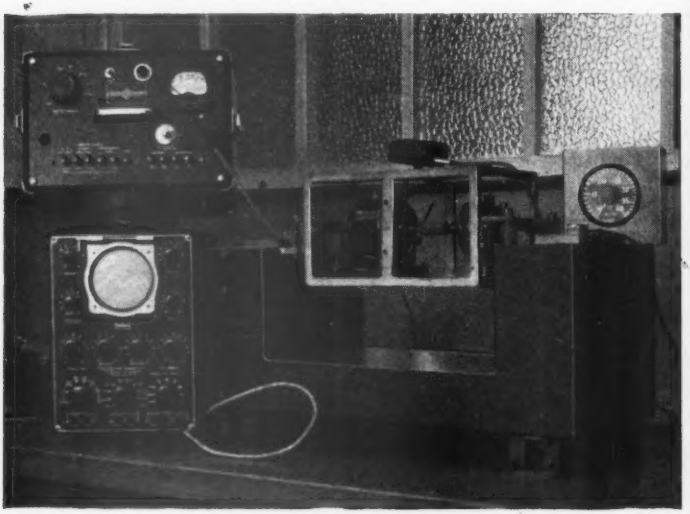

Fig. 7.—Dynamic rubber testing equipment.

harmonic force. It is mounted in a cage supported by four rubber test pieces, to which the pulsating force is thus applied. The speed of the motor and consequently the frequency of the force, can be varied, and is measured by means of an electrical tachometer, while the amplitude of the vibrations imparted to the cage are measured by means of a pick-up and an integrating amplifier. A cathode ray oscillograph is used to monitor the wave form.

The amplitude of the force is easily determined from the value of the unbalanced weight, while the mass of the whole cage is known. Thus, by varying the speed of the motor the resonant frequency and amplitude at resonance are obtained.

From these measurements, we can work backwards to determine the shear modulus and the viscosity modulus of the rubber used in the test pieces, and these constitute perhaps the most important characteristic from the engineers point of view, when applying the rubber as a springing material.

Fatigue Phenomena in Rubber.

Rubber is subject to a fatigue phenomenon of peculiar importance to the engineer, which may be called after Cadwell, the "static fatigue" of rubber.

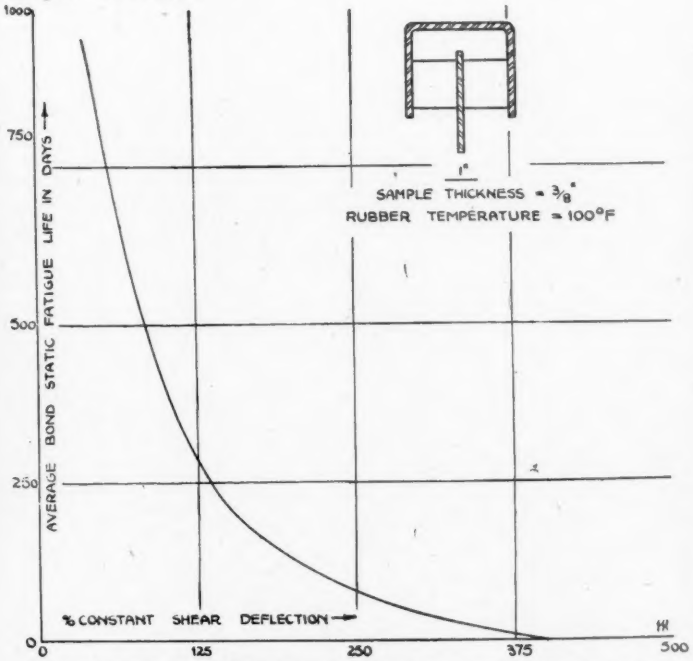

Fig. 8.—Static fatigue of rubber shear sandwich for a compound with a shear modulus of about 80 lbs./sq. inch.

I mentioned before that a bonded unit has a breaking strength of 350/1200 lbs. per square inch. Should it be submitted, however, to stresses of this order, its life would be very short. The attached curve* (Fig. 8) shows life versus static strain for a given rubber unit,

* Taken from a paper by S. M. Cadwell, R. A. Merrill, C. M. Sloman and F. L. Yost, *S.A.E. Journal*, October, 1941, pp. 442-447.

and it is found that life becomes very long for stresses of the order of 40-70 lbs. per square inch.

We are thus limited to these values of the normal static loads if we want to obtain good life, though we may go to higher values of 100 lb. per square inch or more, for short overloads.

To fatigue due to vibrating stress, rubber shows a remarkable quality of resistance, and is much superior to any metal. Fatigue seems to be due chiefly to the heating up of the rubber through the generation of heat caused by the damping.

No absolute figures can be given, for fatigue limitations under vibration, as they will depend on the possibilities of heat dissipation. One peculiar phenomenon may be mentioned, however, and that is the fatigue life is increased if the strain does not pass through a zero value, i.e., if the vibrating strain is superimposed on a static strain, which is larger than the maximum amplitude of the former (c.f. S. M. Cadwell, etc., loc. cit.).

Acknowledgements.

The author would like to acknowledge his thanks to Messrs. Metalastik Ltd. for permission to publish this paper, to the editors of the *S.A.E. Journal* for permission to reproduce Fig. 8 in this paper from the paper by S. M. Cadwell, R. A. Merrill, C. M. Sloman and F. L. Yost, previously quoted, and to the editors of the *Rubber Age* for permission to reproduce Fig. 4 in this paper from the paper cited by F. S. Haushalter.

THE TRAINING AND PROSPECTS OF THE YOUNG PRODUCTION ENGINEER

Paper presented to the Institution, Coventry Graduate Section, on 6th September, 1943,
by F. P. Liebert, Grad.I.P.E.

SOME months ago I had the honour of representing the Yorkshire Graduate Section in a discussion with the Senior Section on the subject of "The Young Production Engineer—His Training and Prospects." This discussion was subsequently reported in the Institution Journal for March of this year. The Committee of this recently revived Graduate Section in Coventry have asked me to address you today on similar lines. The discussion at the Yorkshire meeting was centred chiefly round the educational side of the subject, but while admitting the extreme importance of this to the Young Production Engineer's training, I propose to deal today more fully with other aspects of training, having particular regard to the potentialities of a Graduate Section as an educational medium.

When the industrial complacency at the beginning of the war, aptly referred to by Mr. G. E. Bailey as "The Menace of the Maginot Mind," had been rudely shattered by Dunkirk, there followed a period of feverish industrial activity. New plants were brought into being and existing plants extended out of all recognition. Though the resources of existing planning and production departments in parent firms were stretched to the utmost, and the available production engineers distributed to the best advantage, there was a considerable shortage of men possessing the necessary production experience to meet the requirements of this expansion. Thus, men were brought in to manage production departments, who, although possibly possessing some administrative ability or specialised technical skill were completely lacking in production technique. At that time, however, the only consideration was the turning out of munitions and equipment. Cost and economic production were ignored, and the lack of efficient production engineers was but one of a number of unavoidable wartime conditions. Under the steadying influence of continuous production, however, and as raw materials and supplies of fresh labour became daily more scarce, the need for economic production and efficient utilisation of men, material, and machines becomes correspondingly urgent. The keener interest taken today in such subjects as Quality Control, Machine Utilisation, and the Conserva-

tion of High Speed Steel, bears witness to the universal recognition of this need. Attempts are also now being made to rationalise the hastily formed structures of industrial organisation, as is shown by the recent publication by the British Standards Institution of a B.S.S. on the Principles of Production Control. This will however only alleviate the position. The " cure " can only be the training of a band of fully qualified Production Engineers. Due to the nature of the qualifications required, this cannot be accomplished by dilution and upgrading, but only by sound education and extensive practical training.

To illustrate this point we must consider the scope of the production engineers job. He must be conversant with, and have a good working knowledge of the functions of each of the following departments and sections: Manufacturing, Jig and Tool, Operation Planning, Estimating and Ratefixing, and Machine and Labour Utilisation. These constitute the field in which the production engineer proper will function. Should he wish to rise, however, to the position of Production Administrator, he will have to embrace the additional functions of the production control sections: Scheduling, Progress and Stores Control.

Many will probably disagree with this definition of the sphere of influence of the production engineer, as there appears to be considerable confusion in many minds as to What is production engineering ? and Who is a production engineer ? This would appear to spring from two factors, both connected with the ranks from which production engineers have been drawn in the past. In the first instance there is a tendency on the part of planning engineers, ratefixers, and the like to consider themselves as production engineers on the basis that the function of their department is part of the production function. Secondly—due to the fact that in the past particularly in medium and small organisations, the management alone exercised control of production, production engineering has come to be regarded as part of the management function.

With regard to the first point; although planning and ratefixing are part of the production function, unless the planner or ratefixer increases his sphere of influence to embrace the other sections enumerated above, he cannot truly be said to be a production engineer. As long as planning or ratefixing are his ultimate aim, his scope is limited, and he tends to view all problems from that particular angle. The true production engineer must be able to integrate the requirements and function of all sections to form the production plan.

With regard to the second point; it is true that a chief production engineer must have authority to execute the results of his work, but that authority is no greater than that of the machine shop superintendent or chief inspector, and like these two he would

normally be responsible to the general works management. Further, in a large organisation, the chief production engineer would have under him a number of junior production engineers to look after the production plan in various sections of the works. Thus, whereas management personnnel are drawn from the senior officials of existing departments, production engineering can be a unit on its own, and production engineers should be trained up from the start as such. Therefore, on the question of training, we consider production engineering as a career, education and instruction in which can, and should be built up in successive stages from early youth.

The important factor in preliminary education for all engineers is that it should be general, and in no way specialised. The development of the qualities of self-reliance, sportsmanship and the ability to think quickly and rationally is far more important than the acquisition of a mass of technical data which may never be used and which could be learned more readily at a later date. This is particularly applicable to the production engineer, who must have an agile and adaptable brain, able to rise above accepted procedure and narrow lines of thought, in the face of considerable prejudice and opposition.

There are, however, certain factors in our National Life which run counter to this idea. One is the necessity for a boy to enter a trade on leaving school at the age of fourteen, in order to add to the family income. The proposed raising of the school leaving age to sixteen is welcomed in this respect, and it is to be hoped that the extra two years will not be spent in specialisation. Another factor is the effect of home life on the boy. Hopeful suggestions have been made regarding a new type of Public School which aims at providing the right type of general preliminary education away from the softening influences of home and parents.

This preliminary training should be followed by a period of general technical engineering training in which the theoretical and practical training should follow parallel courses in equal proportion. Under most existing schemes, a youth can have either one or the other. On the one hand we have the apprentice in the factory, with considerable practical knowledge, much of which is too "local" in character to have any educational value; on the other hand we have the student, crammed with a wealth of technical information, but with little idea of how to apply it, and with little or no experience of conditions in the factory. Even when theoretical training is provided at the same time as practical training, the theoretical is often imparted at night school under the worst possible conditions, i.e., when the youth is tired after a long day in the shops, and where the lecturer has already taken classes in a full-time day course. He, too, is probably not up to his best form.

While talking on this subject to a technical school lecturer, he stated that, in taking day and night school classes in the same subject, he had found a marked inability on the part of the night school students to appreciate the finer shades of meaning in his lectures.

Reverting for a moment to the two extremes. At a later stage, the youth with practical experience will probably seem to be ahead of the theoretical man, but the latter will rapidly overhaul him, due to a better ability, to absorb new ideas and to pick out the essential facts in a mass of data. Neither of them, however, will be able to keep pace with the youth who continually and at all points has his technical knowledge correlated to his practical experience.

In order to obtain the desired result, the education authorities responsible for the technical training and industrialists responsible for the practical side will have to co-operate more closely in the future than has been usual in the past. Probably the best method of implementing this would be by state supervision through the medium of a State Indentured Apprentice Scheme.

Towards the end of this period of general engineering training, introduction to the specialised fields of engineering such as: Design Production engineering, Sales technology, etc., should be given in the form of elementary training, both theoretical and practical. This is desirable so that when the time comes for the young engineer to make a choice of a career, he has a balanced idea of the functions and possibilities of these various branches.

Guidance in the selection of a career is a subject which has not received sufficient attention in the past. For most of us, the reasons which led us to adopt engineering as a career seem to have been most haphazard, and our knowledge of the opportunities available vague in the extreme. Apart from organised vocational guidance from industrialists and education authorities, there should also be a number of psychological tests made to determine whether the youth is suited to an engineering career, and later as a guide to the branch of engineering in which he is most likely to be successful.

It will be noticed that no attempt has been made to fix the ages at which the various stages discussed above should start and finish, or of the length of time required to complete any particular stage. Opinions vary considerably on this question, and it would appear that the age and length of training depend largely on the primary education of the boy, and the facilities available in the town in which he takes his subsequent training.

Assuming that the decision is to specialise in the field of production engineering. We now examine the case for advanced production training. Here again the need is for well balanced

practical and theoretical training, although now it may not be desirable or practicable to run these concurrently. The practical training would necessarily demand a measure of responsibility in the factory organisation, thus requiring continuity of activity. The theoretical training calls for a full time day course at a university or technical college, in order to fix sound basic principles in the mind of the young production engineer. This question of theoretical training in production engineering is one in which we lag behind other countries, a fact recognised by the Institution as shown by the pioneer work they have done in implementing the formation of a Higher National course in production engineering. Unfortunately expansion along these lines is proving to be extremely slow and the facilities will have to be greatly extended before the position becomes satisfactory. Carrying the theoretical training to its logical conclusion we look forward in the not too distant future to the endowment of a chair in production engineering at an English university.

In the short time since its inception, the Research Department of the Institution, under the able direction of Dr. Schlesinger has done sterling work, but they have only touched the fringe of production engineering research. There is a growing need for a body of skilled engineers to formulate the basic principles of production engineering and develop them unhampered by commercial considerations and industrial politics.

The practical training should take the form of successive junior posts in some, if not all, of the departments previously enumerated. It is probable that while working in some, the young production engineer would be able to gain sufficient knowledge of the operation of others, due to the interdependence of their functions. Following this, if the organisation is large enough, the engineer should be given a junior post in the production engineering department. In a smaller factory he should become an assistant to the production engineer, or whoever fulfills that function. His subsequent career should then follow a course of natural development.

It is unfortunate that most talk of revised education and the serious training of production engineers is relegated to that overfull pigeon hole—Post War Planning, in spite of the need for immediate action. Most universities and technical colleges, due no doubt to the shortage of staff and the difficulty of obtaining suitable lecturers, have only been able to offer short courses in individual subjects. Managements form totally inadequate apprentice classes in which the instruction is general to the point of being vague. The State is becoming slowly alive to the necessity, but apparently does not yet consider the matter sufficiently urgent to co-ordinate and implement a sound and efficient scheme.

Thus for the present we are reduced to our own resources for obtaining the necessary instruction in production engineering. Fortunately the fund of knowledge available here is considerable. The attitude of senior members of this Institution to Graduates and Students has always been one of extreme helpfulness and sympathetic interest. Due to this close link between the senior and junior members, there is a wealth of first hand experience of all branches of production engineering always readily available. Normally the graduates only opportunity of contact with the experts in production engineering is limited to access to those in the organisation in which he finds himself. Through the graduate section however, help and advice is obtained from senior members in the district and if necessary we can tap the whole resources of the Institution through the good offices of the Technical and Publications Sub-Committee in London. Thus three main points arise in the value of a Graduate Section from the point of view of training :

(1) By means of lectures and discussions, the opportunity of listening to experts in specialised fields of production engineering and thus obtaining detailed knowledge far in excess of that obtainable from technical literature.

(ii) The opportunity of contact with senior and established production engineers. Production engineering depends largely on the development of individuality and the method of approach to a problem. Thus many of the finer points can only be learned by example. The Graduate Section offers opportunities, not to be found elsewhere, for the young engineer to discuss problems relating to production with senior members either by personal contact or in open discussion, on a basis free from the uncomfortable atmosphere of managerial position and works discipline.

(iii) The opportunity of contact with other graduates from different firms, manufacturing widely different products, by different methods, and who probably have a different outlook regarding production engineering. This opportunity of free discussion, not only helps to develop a sound production technique, but also counteracts the tendency to think only in terms of the methods used in one's own works, and helps to show up defects in the system used.

It is considered important that those responsible for drawing up the programme for Graduate sections should concentrate on production subjects, and leave those of general engineering interest to other institutions and societies. In this connection the programme produced by the Coventry Graduate Section is very well balanced. It remains to be seen whether this is a success or a failure, but the value of these lectures lies, not so much in the subject matter of the address, as in the standard of the

discussion that follows. Thus for successful meetings we must have the support of all graduates in the district. The time required to attend the meetings and works visits will not be wasted either to yourselves, your firm, or the war effort.

One is diffident about talking at length on the subject of future prospects, on account of the ease with which it is possible to indulge in flights of fancy, without due regard to the limiting conditions. Despite the revival of agriculture, and the assurance that this will not again be allowed to fall into decay, we can safely say that the future of this country depends largely on her industrial output. We may not be a nation of brilliant designers, but in the field of development and productive efficiency we are second to none, as has already been proved many times in this war, though we do not make a big song about it like some of our neighbours. Production will be our chief asset after the war, and the way in which we develop it will set the standard of living for the whole country. The task of re-directing the productive drive and experience now being used for the manufacture of instruments of war, to the economic production of peace time goods will be enormous. The man responsible for the success of this colossal changeover will be the production engineer, and to him will be given the task of improvisation and re-organisation and the gradual re-shuffle of machinery, processes and labour. He will need all the sound training and experience he has been able to acquire. As Mr. Churchill would say, therefore : we can look forward with sober confidence to a bright future for Production Engineers.

Discussion

Mr. Riley (Chairman) : We have had a very interesting lecture from Mr. Liebert, quite the best which I have heard on this subject, and the opinions expressed coincide with my own. I feel that most of us agree with the type of training specified by Mr. Liebert and with his remark that the young Production Engineer should be progressive, but are the firms they work for of the same opinion ?

Scientific production control has received very little attention in the past, and I feel sure that when firms realise this and adjust their outlook, the young Production Engineers will be available.

Mr. Boyes : As an old member, I should like to say here and now that I have thoroughly enjoyed Mr. Liebert's paper and the many points which he has brought out which have not been brought out before.

In the first place he mentioned the raising of the school leaving age to sixteen. I hope this will be effected in a very short time.

He also mentioned the effect of parental control, which I would like to emphasise. I think that the guidance of the older genera-

tion, together with the progressive outlook of the younger generation, forms an ideal combination.

I wish to mention another important point. I have met, in my period here, many young fellows who are content to say, because they are designing say jigs and tools that this is the only line in Production Engineering. This is the wrong attitude. They should adjust their outlook to embrace the whole field of Production Engineering.

Mr. R. A. GOLDNEY: I should like to add a few general remarks on the subject of which Mr. Liebert has been speaking.

Firstly, to endorse his remarks regarding the field of activity of the various professional institutions. I think it is very necessary at this stage, and certainly before the post-war years, not only to define the scope and function of these institutions, but to provide also some means of co-ordinating their work so that there is less overlapping.

Secondly, regarding general education in the extra two years which we hope to see added to the normal school life in the near future. General education by all means, but surely we need more than that. There is an urgent necessity for the weaning of the schoolboy mind to the demands of industrial life. He must grow gradually from schoolroom to the industrial workshop; not abruptly, and the transition can be effected in these two years.

Thirdly, with reference to psychological tests I have very little experience here, but it seems to me that your Production Engineer primarily needs:

(a) Manual Dexterity.
(b) Special perception, the ability to read and understand working drawings.
(c) Motor control and reaction tests to determine his analytical ability.

All are essentially simple and fundamental, and it seems to me that the selection of the suitable Production Engineer by means of vocational tests is a fairly elementary matter.

Fourthly, might I add to Mr. Liebert's remarks on the subject of Graduate meetings. The Graduate Engineer has an extremely important function in managerial activity, but Production Engineering deals only with specialised subjects and is in itself an integral part of general engineering which is, in turn, only one of the management functions. Is not management a step further than that? Management is essentially the building of a super-structure of administrative knowledge on the foundation of technical knowledge, and the development of leadership ability and character in the individual. I feel that in this latter sense the Graduate meeting can play an extremely important part.

I deplore the tendency of the Mechanical Engineer to find his ultimate vocation in the field of design or any other purely technical function, and to leave their rightful part in the field of Management activity to salesmen, accountants and the like, who possess a wider knowledge of the field of industrial activity, but a much less reliable background.

Lastly, may I add a particular remark on the attitude of the old school. I am not a fire-brand or sceptic, but I have often asked myself "Has the old school always been as receptive to new ideas as it might have been?" "Is not their part in the progress of industry often hostile to science?" Old and mature people in industry tend to do things the way they have always known it, to forget that progress brooks no tarrying. There are exceptions no doubt, but I attribute some measure of the lack of progress to the attitude of older people. Unless education plays its true part in the training of production, or any other engineers, and until industry is much more willing than it has been to play its part in co-operation with education, nothing can be worked out which will, in its essence, satisfy the real needs of war, and the demands of post-war industry.

Let us not monopolize our ideas with technical progress. The Production Engineer must play his part as a citizen; he must see that his object in life attempts to accord with the maximum satisfaction, with meeting the material needs of mankind. Let the Production Engineer not be limited by his profession. Let him be limited only by his abilities as a citizen.

MR. WILSON (Principal of Coventry Technical College): Mr. Goldney has stolen quite a lot of my thunder. However, I open my remarks by saying there is much discussion going on today regarding training, and I hope these discussions will bear fruit, in particular the discussion on the training of the young Production Engineer. Frankly, in my fairly short experience in evening class work, as a University Lecturer, Technical College Lecturer and now as an Administrator, I find the old traditions are very hard to break down. If you look in the Technical College Syllabus of many years ago, you find the same subjects appearing as today. The manufacturing, as compared with the designing side, has not been given the attention it should have been, therefore I blame industry. Regarding the common ground in the training of young people—there are two common factors as Mr. Goldney says:—

(1) make the young man proficient in his particular calling in life, and;

(2) an educated member of a democratic community or, if you like, a good citizen.

Are we doing that for any young employee, under our present system? I doubt it very much. If you take the ground work

it is all you have in day school. It is the ground work for your pre-entry into industry. This has a very strong fibre of literary and academic dye, which is called general education, but it is not general education unless it has that particular aspect. If you take any interest in educational matters you will have seen the White Paper which has recently been published and general education should now get another chance. Any young man should be able to handle ordinary wood and metal tools ; one would abhor the man who sits reading by the fire and, when the light goes out is at a loss to know what to do in order to mend the fuse, as much as the man who could mend the fuse, but could not understand what the other fellow was reading. Schooling is undergoing various changes. Science, wood and metal work will play a much more important part in future. I hope a keener appreciation of science will be stirred up in every boy going to a school.

I do not want to labour this next point, but if any of you have studied the present educational system of the U.S.S.R., you will find it is based on a system of science. Ours is not. When he has left school, we expect a young man to make himself progressive and continue his education. He can do neither unless he has had education. On entering industry, it then becomes the concern of the industry. Some claim he should be under the educational system until 21, but I do not go so far as to say that. Industry does not come forward to play its part in that direction with education. On entering industry, the young engineer should have a planned training scheme. Some in industry have entered as wage earners for their parents. Very soon I hope that will disappear and that young engineers will enter because they are keen. If keen, the young engineer will have many questions to ask and will expect authoritative answers. If he obtains these answers, his training will go forward at an amazing speed. In olden days, questions were unanswered. I could give you many instances in my own training in the workshop. Answers should always be given to the young engineer. First of all the young man should spend most of his time in contact with actual production. He should meet men engaged on production and if keen enough, study them. He should be given, during this period, certain times in the Work's school and he should ask questions. I have put this to several people, who say in the larger firms it is possible but there are very many small concerns where it would be impossible to set aside a training bay, to which young men could go for certain periods each week. The education authority and industry should co-operate and play an important part, Workshops in the Technical College should be available for the personnel of smaller concerns.

Concurrent with this training, should be a form of technical

studies, and I am talking of the young man up to 16, starting in the Workshop, until the age of 19. He has his experience in the workshop, plus special training in the Work's school or technical college. In addition, he should have his technical studies and a continuation of technical education. One field of thought today is that technical classes are too technical, and it would be my aim, if I had the accommodation, staff and purse at my disposal, to give our technical students a broader education up to 19. Until this age, you are training a young engineer. You should now cross section the young fellow's ability. Now is the time to decide whether he will go on with studies at a technical college or whether he should go on to a University. I regard this age of 19, and this training up to 19, as extremely important and, if I may quote Dr. Priestley of Birmingham University, and Chairman of the Joint Recruiting Board, Birmingham, who has had an opportunity of coming into contact with hundreds of young men who have had this training (not as completely as I should have liked, he says in a paper the personal ability, perseverance, grit and sportsmanship of the fellows who have worked in the technical colleges are far ahead of his Undergraduates. He would like to introduce them into his college to meet his undergraduates. At Birmingham University they have agreed to accept the second year course as parallel to the National Certificate. Never before in the history of education has the ordinary national certificate been accepted as being on that parallel, so I take from 16 to 19 years as a very vital part in a young man's training.

If he is to be a Production Engineer, I can only say he is a man concerned with the manufacturing side. At 19, the firm's Supervisor should know full well whether the fellow has ability in one sphere or another. It is then up to Engineering, Industry and Education to give that man the special training he needs. There is no reason why industry and education authorities cannot get together and produce the right type of training for such a young man.

If this specialised training begins at 19, how long should it continue? Personally I do not think it need continue very long, if tackled in the right way. We waste a lot of time in training young people, and we waste a lot of time in giving specialised training which is unnecessary. It is not a waste to give a general background. I believe industry could do a great deal in training the people we have in mind (from 19) by specialisation.

The whole problem seems so simple to me that frankly I do not know why there should be a lot of discussion. A young man cannot be a successful production engineer unless he is always a good citizen. He must have a good general education to enable him to carry on his education, general engineering ability and then special-

ized training. It is up to Engineering, Industry and Education to work it out.

MR. JACKMAN: I should like to put one direct question to Mr. Liebert. We have heard a lot about practical and theoretical training. What in Mr. Liebert's opinion is the correct ratio between the two? From my experience I should say it would amount to 90% practical and 10% theoretical, and that is why you have difficulty in breaking down tradition in factories today.

MR. LIEBERT: Until recently, the theoretical training available has been very small. A short while ago it was non-existent. Now, however, due to the efforts of the Institution, culminating in the formation of a Higher National Certificate in Production Engineering, we have a recognised course of theoretical training in this subject. The formation of this course must have been difficult due to the wide field to be covered. Production Engineers did not spring fully armed from the head of industry as a working unit. They have been evolved slowly out of a growing need, as industrial undertakings have expanded and become more specialised. This need is a practical one, therefore practical men with practical training have become Production Engineers. This does not mean, however, that there are no principles or fundamentals of production engineering, requiring to be taught by theoretical training. There is a very great need for considerably more theoretical training, and I should say that for a balanced study of Production Engineering, the amount of theoretical training should be equal to the practical.

MR. RILEY: One point about the educational side is the type of factory chosen as an example for text books on Production Control. They are invariably Factories which enjoy all the best possible conditions and are engaged on mass-production. This simplifies the details of Planning, Progressing, Plant Utilisation, etc. In view of the fact that most Factories in Coventry are engaged on varied batch production, I suggest to Mr. Wilson that in such subjects as "Workshop Organisation and Management," consideration be given to the control of varied production.

MR. J. J. ISAAC: Do you expect the firms to train thoroughly and produce the men who are to become the future Production Engineers?

I doubt whether many firms today can allow the time for junior engineers to have experience in the many specialized departments mentioned, their main concern being to produce the work.

Careful changes of situations after apprenticeship (when permissible) give valuable experience to the young engineer, who may return to the works where he was initially trained, taking with him many new ideas and new methods of production, therefore becoming a better asset to his firm.

Dealing with technical training, may I suggest to Mr. Wilson that consideration be given to bring the lectures more in keeping with the students every day work (i.e., to give training in design of jigs and fixtures, time study, etc.). This would prove very valuable in conjunction with the practical training he receives in the workshop.

MR. CORNELL: It is very discouraging to find that if a young engineer proves to be particularly adept at a job, that his firm are most reluctant to move him for his own advantage and training. This is especially true of industry today.

MR. LIEBERT: It is true of most works today that when an apprentice finds himself in a department or position for which he may have a flair, the firm are very unwilling to move him to another department. This is a responsibility of the management. They should be sufficiently far sighted to appreciate the need of Production Engineers and, having appreciated it, to ensure that some at least of the more promising graduates and student apprentices are given a sufficiently wide experience in the production departments of the firm, to fit them to become Production Engineers. Where the management are not appreciative of this point and the apprentice still wishes to become a Production Engineer, it is up to him to get himself moved from department to department.

With regard to Mr. Isaac's question, as to whether firms can afford to allow the time for junior engineers to go through these various departments, I would emphasise again that Production Engineers grew out of a definite need in the industry and that therefore it is in the firm's own interests to train them adequately. There are certain firms who have gone out of their way to train a sufficient number of young engineers. I believe that Metropolitan Vickers, Ltd., train almost more engineers than they can absorb in their own organisation and the Bristol Aeroplane Company have a course of such a high standard that it is accepted by the education authorities as equivalent to the National Certificate course, and National Certificates are given to successful candidates.

I am grateful for the endorsement of my views by Mr. Riley. There is one point in which graduates can make an immediate contribution to the war effort. At this time senior members are necessarily having to concentrate on the particular production problems in their own Works. This is a full time job and leaves them with little or no time to experiement with new ideas or methods such as quality control, etc. There is, however, great scope for the Graduate here to try out and experiment with such methods. Having discovered whether the particular process under consideration is suitable in its original plan, or can be adapted to suit the

existing organisation, he can then put the results of his researches before his chief for a final decision.

I agree with Mr. Goldney that further co-operation between the various institutions is desirable and also that a more exact definition of the function of the various institutions is required. We must not forget, however, that the various institutions do combine on many occasions to draw up reports and provide advisory committees on questions of national importance.

On the question of vocational tests and the reasons why these have not been applied more fully in the past to the selection of Engineers, I think the chief reason is that all new ideas are treated with suspicion in this country. Psychological selection is not generally applied in industry, but I agree that there should be far more in the way of vocational tests.

Regarding his remarks on management, I agree that Production Engineers should keep an eye for the future in this respect, but it is a matter coming outside the scope of this lecture which is concerned only with the Production Engineer.

I would like to thank Mr. Wilson for the excellent way in which he has put his point of view, with which I am generally in agreement.

I also thank you all very much for listening, and for the enlightening discussion.

(Vote of thanks given by Mr. Lloyd).

Research Department: Production Engineering Abstracts

(Edited by the Director of Research).

NOTE.—*The Addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough. Readers applying for information regarding any abstract should give full particulars printed at the head of that abstract including the name and date of the periodical.*

ANNEALING, CASEHARDENING, TEMPERING.

The Fundamental Concepts of Tempering, by A. E. Focke. (*Machinery-Lloyd, 1st April, 1944, Vol. XVI, No. 7, p. 37, 10 figs.*).

Purposes of the tempering operation. Fundamentals of tempering and results of recent investigation. Use of quasi-solid diagrams to show three dimensional relationships. Relationship between time, temperature and hardness for various steels including H.S.S. Relation of torsion impact values to tempering temperature and time. Relation of Izod impact values to tempering temperature. Relation of crushing strength of carburised N.E.8620 cylinders to colouring temperature and time. Relation of deflection at breaking load of carburised N.E.8620 cylinders to colouring temperature and time. Relation of static crack strength to tempering temperature and time. Change in length of high speed steel. Full bibliography.

The Salt Bath Heat Treatment of High Speed Steels, by J. M. Pethebridge. (*The Australasian Engineer, 7th January, 1944 Vol. 44, No. 332, p. 22, 11 figs.*).

A particular application. Molten salt as a source of heat. Advantages. Chemical considerations. Equipment and constructional details of immersed electrode furnace. "Starting salt." Temperature control. Operation. Troubles. Hot quenching. Straightening operations. Precautions. Hardening slab milling cutter. 17 in. × 6 in. dia. × $3\frac{1}{8}$ in. bore. Electrical maintenance. Maintenance of metallic materials, refractories and salts. Advantages and disadvantages of the method. Quality of product. Economics.

BELTS, ROPES.

Selection of V-Belt Drives, Parts I and II, by H. A. Wilson. (*The Machinist, Reference Book Sheet, 8th April, 1944, Vol. 87, No. 51, p. 119*).

The econograph sheave selector chart developed by Texrope engineers enables designers to solve for six variables and determine an economical drive with the fewest V-belts. The chart will solve V-belt drives regardless of make.

COMBUSTION, FURNACE.

Coil Design for Successful Induction Heating, by F. W. Curtis. (*The Machinist, 1st April, 1944, Vol. 87, No. 50, p. 94, 6 figs.*).

Part II. Continuing his analysis of coil design the author points out some vital considerations for the successful application of H.F. brazing and hardening.

FOUNDRY, MOULDING, PATTERNS.

Reclamation of Porous Castings. (*Industrial Gas Times, March, 1944, Vol. VII, No. 78, p. 143, 1 figs.*).

Slightly porous castings made serviceable by impregnation with a synthetic resin. The process in brief. Operating procedure. A typical job. Stoving.

JIGS AND FIXTURES.

Interchangeability Media for Airframes Largely Built by Government Trainees. (*Production and Engineering Bulletin, April, 1944, Vol. 3, No. 17, p. 169, 15 figs.*).

How a firm building large assembly fixtures and gauges for the production of aircraft structures introduced optical measuring methods and a special procedure so that trainee labour could be employed. A form of toolmaking that is in a class by itself. Metrology. Using a pair of theodolites for the accurate measurement of large components. Methods of construction used. Description of various examples. Type of employee and training.

LIGHTING.

Emergency Lighting Systems and their Applications, with Particular Reference to Battery Equipments, by S. H. Chase. (*The Journal of the Institution of Electrical Engineers, April, 1944, Vol. 91, Part II, No. 20, p. 132, 12 figs.*).

In recent years there has been an increasing call for the installation of emergency—sometimes termed "alternative" or "secondary"—lighting systems. These can be provided by candles or nightlights, gas, dry-or wet-battery torches, accumulators, engine-generator sets, alternative independent mains supply, or by a combination of several methods. The amount of emergency lighting may range from an intensity equal to normal down to the minimum considered necessary for safety and continuation of essential services. This paper deals mainly with the use of accumulators for standby purposes, operated either manually or automatically upon failure of the mains supply and capable of supplying loads for varying periods according to the class of installations, which are grouped under five heads.

MACHINE ELEMENTS.

The Effectiveness of Shear-Stressed Rubber Compounds in Isolating Machinery Vibration, by B. C. Madden, Jr., (*Sheet Metal Industries, April, 1944, Vol. 19, No. 204, p. 663*).

This paper is concerned with determining the effectiveness of rubber compounds in resilient mountings in the isolation of vibrating machinery where the rubber compound is stressed principally in shear. Seven rubber compounds were investigated. Certain considerations to be taken into account when appraising the effectiveness of a resilient mounting are stated. A dimensionless criterion is developed for the effectiveness of a rubber compound in terms of physical properties measurable by testing apparatus. The criterion is evaluated for each of the seven compounds. The results indicate that the criterion is worthy of consideration.

Rubber as Material for Bearings, by S. A. Brazier and W. Holland-Bowyer. (*Power Transmission, April, 1944, Vol. 13, No. 147, p. 296, 3 figs.*).

Coefficients of running friction for typical materials. Action of a water-lubricated rubber bearing. Scoring. Resistance to the combined cutting action of abrasives. Examples. Centrifugal sand pump. Hydraulic turbine. Stern tube bearings. Borehole centrifugal pumps. No upper limit to

speed. Lower limit. Pressures. Deflection. Length. Types of rubber bearing. Main differences found with regard to type of lubrication necessary. Service conditions determine type used. Requirements for successful operation.

MACHINING, MACHINE TOOLS.

Calculations for Screw Machine Cams, by A. Ainsworth. (*The Machinist, 15th April, 1944, Vol. 88, No. 1, p. 91, 2 figs.*).

Five tried methods for figuring thread lobe rise on Brown & Sharpe automatics, together with explanation as to when and why they are used.

Grinding Procedures set for Glass Gauges. (*The Machinist, 15th April 1944, Vol. 88, No. 1, p. 83, 8 figs.*).

Close tolerances and transparent finishes on these gauges require deviations from usual grinding practices. They are recommended only after feasible applications have been set up for each gauge.

Testing the Suitability of Abrasive Wheels and the Machinability of Metals by Temperature. (*Machinery, 6th April, 1944, Vol. 64, No. 1643, p. 374, 3 figs.*).

Devices to test grinding wheels in order to find out the best abrasive wheels for the machining of a specific material and to establish an order of the machinability of these materials by grinding. Results of grinding wheel tests with wheels of varying grain and hardness. Results indicating the machinability of different materials with two different brands of fine-grained wheel.

Time and Rate Fixing on Grinding Wheel Truing, by F. L. Meyenberg. (*Industrial Diamond Review, April, 1944, Vol. 4, No. 41, p. 78, 2 figs.*).

The regular truing of grinding wheels is necessary in order to keep the accuracy and the surface finish of the work produced within the required limits. The interval between the individual truing process can either be left to the discretion of the operator or perhaps better still be made according to the instruction of the planning or production engineer. Truing immediately prior to the finishing cut is recommended for workpieces of high accuracy. The truing time analysed. Centreless grinding.

Cutting Large Keyways on Vertical Shapers. (*Machinery, 27th April, 1944 Vol. 64, No. 1646, p. 454, 1 fig.*).

The versatility of the modern vertical shaper is being used to advantage in machining large keyways in heavy cumbersome pieces. A typical example is given.

Production Milling. (*Automobile Engineer, March, 1944, Vol. XXXIV, No. 447, p. 102, 4 figs.*).

Notes concerned solely with milling as a means of economically producing repetition parts. The general principles employed for cutter design and mounting and the speeds and feeds that are representative of modern milling machine practice are discussed in detail. Descriptions are also given of various actual applications on Cincinnati plain automatic milling machines. These illustrate the use of the reciprocating table cycle with right- and left-hand fixtures to reduce idle time by allowing one fixture to be unloaded and loaded while the other is in the working position, and the use of a multiple set-up to allow two or more operations to be performed at one set-up. A subsequent article will deal with typical hydraulically operated milling machines.

CHIPLESS MACHINING, FORGING, PRESSING.

Forming Aluminum, by J. Wilford. [*The Tool Engineer, (U.S.A.), February, 1944, Vol. XIII, No. 2, p. 65, 5 figs.*].

Taking advantage of the " set " obtained by adding stretch to the bending of aluminium shapes, the Goodyear Aircraft Corporation has developed a machine for mass production which eliminates springback and hand work. Complete details are prefaced by other data on aluminium forming progress.

The Production of High Grade Forgings, by J. Winning. (*Mechanical World, 28th April, 1944, Vol. 115, No. 2991, p. 455, 4 figs.*).

Inspection features. Dimensional accuracy. Allowance for flash. Deeply cut dies. Wear. Wear and misalignment caused by the use of " stepped " dies. Design influence. Accuracy of composition. Difficulties experienced with case-hardening and alloy oil-hardening types of steel. Effect of poor heat treatment plant. " Quality " of steel. Inclusions. Transverse weakness. General flaws. Errors in heating prior to stamping. Cooling after forging. Effect of electric heating. Amount of inspection required.

Light Alloy Pistons, by C. Wilson. (*Automobile Engineer, February, 1944, Vol. XXXIV, No. 446, p. 53, 12 figs.*).

Forging or moulding by plastic deformation takes many forms, and the author of the accompanying notes surveys various methods, more particularly in relation to the requirements of high duty pistons. The materials for highly stressed wrought and forged pistons are surveyed, and the influence of fabrication methods is considered. Individual forging of cast blanks, and its relation to grain flow is studied and some typical test results are given. The importance of grain is stressed, particularly as it influences the maintenance of a constant quality in the product. Materials. Forging methods. The forging process. Consistent quality. Moulding technique. Press forming. Moulding dies. Future development.

Small Steel Pressings, by J. A. Grainger. (*Sheet Metal Industries, April, 1944, Vol. 19, No. 204, p. 677, 9 figs.*).

Presswork. Types of presses. Applications of presswork in modern industry. General problems. Damaged work and dies. Lubrication. Cleanliness of the work. Speed of the press. Development in design.

MANUFACTURING METHODS.

Closely-spaced Holes in Small Disc. (*Machinery, 13th, 20th, April, 1944 Vol. 64, Nos. 1644, 1645, pp. 411, 437, 11 figs.*).

The problem is set to find the best method of holding a 12 s.w.g. Dural disc and drilling four accurately spaced $^1/_{10}$ in. diameter holes on the assumption that large quantities of the discs have to be produced. Details of five separate solutions of the problems are given.

MATERIALS, MATERIAL TESTING.

Magnesium Alloy Technology, by F. A. Fox. (*Met. Ind., 18th, 25th February, 3rd March, 1944, Vol. 64, Nos. 7, 8, 9, pp. 101, 114, 133*).

A general paper, dealing with British and American alloys, casting characteristics, heat treatment, choice of casting alloys and wrought alloys, surface treatments, machinability, damping capacity, uses.

(*Communicated by the British Non-Ferrous Metals Research Association*).

MEASURING METHODS, APPARATUS.

5-Wire V-Block Measurement. [*The Tool Engineer (U.S.A.), Production Data Sheet, February, 1944, Vol. XIII, No. 2, p. 97, 1 fig.*].

Diagrams and formulas to transpose 3-wire thread measurements to 5-wire V-block thread measurements, also for reverse transposition. Used to measure pitch diameters of taps with odd numbers of flutes. These formulas use, as a base, the 3-wire thread measurement "M," including the helix angle correction, if any, and are applicable to all thread forms without change because "M" includes the thread form formulas. "R" is the dimension obtained by direct measurement.

Gauging the Tooth Thickness of Helical Gears, by A. Ryding. (*Machinery, 6th April, 1944, Vol. 64, No. 1643, p. 371, 4 figs.*).

Determination of M for a helical gear. Types of gauges used for checking tooth thickness. The derivation of the constant C, the hypothetical normal pitch radius. Graph giving the relation between C and the spiral angle. Diagram showing how M may be easily converted to include a different number of teeth.

Workshop Measurement to One-millionth of an Inch. (*Machinery-Lloyd, 15th April, 1944, Vol. XVI, No. 8, p. 52, 7 figs.*).

Optical flats. Underlying theory. Interference band patterns of common occurrence. Convex and concave surfaces. Measurement of the diameter of a cylindrical gauge. Measurement of the effective diameter of screw gauges. Measuring the diameter and checking the roundness of steel balls. Convenient light sources.

MECHANICS, MATHEMATICS.

Balancing Rotating Apparatus—II, by R. P. Kroon. (*Journal of Applied Mechanics, U.S.A., March, 1944, Vol. 11, No. 1, p.A.47, 15 figs.*).

Shop balance methods. More elaborate shop balancing; field balancing. General discussion of field balancing. Nonlinearity. Operating conditions. New balance planes. Local resonance.

PHOTOGRAPHY, X-RAYS.

Application of Electron Microscope to Study of Aluminum Alloys, by F. Keller and A. H. Geisler. (*American Institute of Mining and Metallurgical Engineers, Technical Publication No. 1700, February, 1944*).

Some of the important changes that take place in the structure of aluminium alloys are largely submicroscopic in character. This is especially true of the changes that accompany age-hardening and recrystallization. Although improved metallographic practices have been helpful in indicating some of these changes indirectly, results are limited by the resolving power of optical microscope lenses. The electron microscope provides a new means for investigating the fine structure of metals.

(*Communicated by the American Library, U.S. Office of War Information*).

Radiographic Inspection. Non-Destructive Examination of Welds, Part II, by L. Mullins. (*Welding, April, 1944, Vol. XII, No. 5, p. 179, 6 figs.*).

Making the radiograph. Interpretation of radiographs. Layout of the department. X-rays in welding research. References.

PLASTIC MATERIALS, POWDER METALLURGY.

Plastic Four-wheeled Passenger Van. (*The Engineer, 10th March, 1944, Vol. CLXXVII, No. 4600, p. 188, 5 figs.*).

A new design of four-wheeled passenger van. The advance made in recent years in the manufacture of plastic materials has been remarkable, and the new materials have qualities which make them suitable for incorporation in rolling stock.

Design and Application of Phenolic Decomposition Bearings, by O. L. Graef. (*Power Transmission, April, 1944, Vol. 13, No. 147, p. 254*).

Introduction. Bearing composition. Properties of bearing. Mechanical strength compares with cast iron. Design fundamentals. Thickness of liner. Clearance. Seat. Arc of contact. Cooling. Location. Alignment. Shut down periods. Examples.

SMALL TOOLS.

Corrected Diameters for Circular Form Tools—Parts I and II, by B. S. Sample. (*The Machinist, 22nd April, 1944, Vol. 88, No. 2, p. 81, 1 fig.*).

Calculations for circular form tools without rake.

Carbide-Tipped Cutters Speed Steel Milling, by F. W. Lucht. (*The Machinist, 8th April, 1944, Vol. 87, No. 51, p.327E, 8 figs.*).

Material prepared by Carboloy Company, Inc., with a view to clarifying the fundamentals involved in the design and use of carbide milling cutters for machining steels. The information is based on a survey of numerous steel milling applications in almost every branch of the metal-working industry, correlated with an analysis of the basic cutting tool principles involved. Cutting and relief angles. Number of teeth and power. Fly-milling cutters. Machine requirements. Operating precautions. Climb milling vs. conventional milling. General considerations.

Cemented Carbides, by M. Littmann. (*Automobile Engineer, February, 1944, Vol. XXXIV, No. 446, p. 59, 12 figs.*).

A wide range of cemented carbides are now available, each with its own specific properties. In this country the normal practice is to use only a single grade in any one tool, but German developments have shown that a combination of two or more grades will frequently give a greater working efficiency. The accompanying notes give examples of recent German practice in the application of several grades of cemented carbides to various tools. Groups and grades of cemented carbides. German tool developments.

Chip Control in Machining Steel with Carbides, by E. Almdale. (*Canadian Machinery, February, 1944, Vol. 55, pp. 87 and 160*).

Effect of chip breaker on tool life. Chip breaker design. Chip breaker types. Control of chips. Grinding. The diamond wheel should not touch the wheel shank. Reversing of wheel will give more even wheel wear, and avoid necessity of reshaping the wheel at regular intervals.

(*Communicated by The Diamond Research Department*).

Save the Pieces, by E. W. Martin. (*The Tool Engineer (U.S.A.), February, 1944, Vol. XIII, No. 2, p. 89, 4 figs.*).

Tool reclamation. 1. Preheating. 2. Cleaning. 3. Fluxing. 4. Welding. 5. Rough Grinding. 6. Finish grinding. 7. Testing. 8. Records. Heat treat before welding.

Feinstschleifen von Hartmetallschneiden bei sparsamster Verwendung von Diamantschleifscheiben. [*V.D.I. Zeitschr.* (*Germany*), *Vol. 87, 1943, pp. 111—112*].

Fine grinding of hard metal cutting edges with most economical use of diamond wheels. Composition and use of silicon carbide wheels. Use of diamond wheels and their composition.

(*Communicated by the Diamond Research Department*).

Floating Reamers. (*Automobile Engineer, February, 1944, Vol. XXXIV, No. 446, p. 69, 2 figs.*).

Internal balance. Construction. Setting and adjusting.

The Wire Drawing Die, by F. C. Elder. (*Wire and Wire Prod., January, 1944, Vol. 19, No. 1, pp. 23, 25, 32*).

Deals with the effect of die shape upon steel wire drawn dry through tungsten carbide dies.

(*Communicated by the British Non-Ferrous Metals Research Association*).

SURFACE, SURFACE TREATMENT.

Surface Finish, by W. E. R. Clay. (*Paper of the Institution of Automobile Engineers, February, 1944, Price 4/-*).

A survey of methods and equipment for measuring the roughness and waviness of surfaces; standards and manufacture of standard test pieces; effects of improved surface finish and surface finishing processes. Application to aero-engine manufacture.

Interference-band Inspection of Surface Finish. (*Engineering, 17th March, 1944, Vol. 157, No. 4079, p. 205, 3 figs.*).

A simple and rapid method of assessing the smoothness of large quantities of small components, analogous to the sizing of such components by the comparator type of instrument. The new method is based upon the well-known phenomenon of interference. The microscope method is only applicable to finely finished flat or convex surfaces and, in general, is not suitable for surfaces of which the average height of the irregularities above a mean line exceeds 20 micro-inches (1 micro-inch = 0.000,001 in.). A further limitation lies in the size of the part that can be examined since this must be capable of being placed on the stage of the microscope.

Electrolytic Methods of Polishing Metals, Part I, by S. Wernick. (*Sheet Metal Industries, April, 1944, Vol. 19, No. 204, p. 613, 2 figs.*).

Disadvantages of mechanical polishing. Contamination of the atmosphere. Removal of metal. Cost factor. Origins of electrolytic polishing. Theoretical basis. History of the process.

Metal Colouring: Decorative and Light-Duty Finishes, by H. Silmon. (*Sheet Metal Industries, April, 1944, Vol. 19, No. 204, p. 653, 6 figs.*).

Applications. General methods. Initial finish. Methods used. "Electrocolour" process. Treatment of steel and iron. Caustic alkali-nitrate processes. Characteristics of black oxide coatings. Phosphate coatings. "Bonderizing" and "granodizing." Cold process phosphate treatment.

Phosphate Coated and Lacquered Steel Sheet as used for Food Can Manufacture, Part II, by L. Schuster. (*Sheet Metal Industries, April, 1944, Vol. 19, No. 204, p. 635, 1 fig.*).

Large scale production. Details of mechanised layout. Electric controls. Chemistry of the phosphate process. Practical test methods for bonderized cans. Conclusion.

WELDING, BRAZING, SOLDERING.

Welding Research, by W. C. E. Barnes. (*Welding, April, 1944, Vol. XII, No. 5, p. 197, 5 figs.*).

Laboratories of the Arc Manufacturing Company. These research laboratories have been developed gradually from the chemical laboratory which was opened in 1938. Welding research laboratories. These consist of an experimental extruding laboratory, a mechanical test room and the welding laboratory proper. The plastics laboratory. In view of the extensive development of plastics and the increasing interest shown in them by the engineering world, it was decided in 1941, to carry out investigations regarding the welding of these materials. When it was found that the welding of thermoplastics offered distinct possibilities a new branch was opened to carry out research in this field. After a short time, however, this branch was reincorporated in the other laboratories.

Better Welds through Regulated (Resistance) Welding Current, by B. Cooper. [*Welding J. (J. Amer. Weld. Soc.), U.S.A., January, 1944, Vol. 23, No. 1, p. 5*].

Describes a control for eliminating variation in resistance welding current due to changes in the power supply voltage and power factor and impedance of the welding transformer and load.

(*Communicated by the British Non-Ferrous Metals Research Association*).

Cycle-Welding Breaks the Barrier to Assembly with Cement Bonds. (*The Machinist, 22nd April, 1944, Vol. 88, No. 2, p. 12E, 16 figs.*).

Aircraft applications now predominate but the time and cost savings already realized on structural products not designed for the process indicate enormous possibilities for new constructions in the postwar period. Three processes available. Wood to metal joints. Pressure pads.

The Strength of Glued Joints, by N. A. de Bruyne. (*Aircraft Engineering, April, 1944, Vol. XVI, No. 182, p. 115, 11 figs.*).

Apart from this new extension of gluing to the metal working trades synthetic adhesives have already revolutionised the woodworking industries. This revolution is due to the superior quality of the resulting products and the increased rate of output made possible by the intrinsic high speed of setting of synthetic adhesives aided by such novel methods as high frequency heating, infra-red heating and the like. In aircraft in particular the " weather-resistance " of synthetic adhesives has largely removed the disadvantages of wood construction, due to the use of casein glues, so much in evidence in the first winter of this war. Before engineers can use gluing in the fabrication of structures they must be provided with data sufficient to enable them to compute the strength of the joints. A simple relation between the strength of a lap joint and its geometry. Such a simple relation is found in " the joint factor " which is defined as the square root of the thickness of the sheet divided by the length of the overlap.

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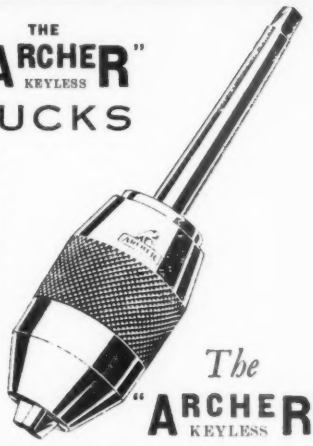

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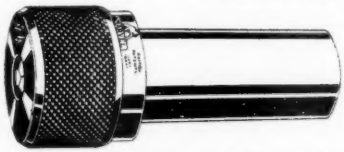

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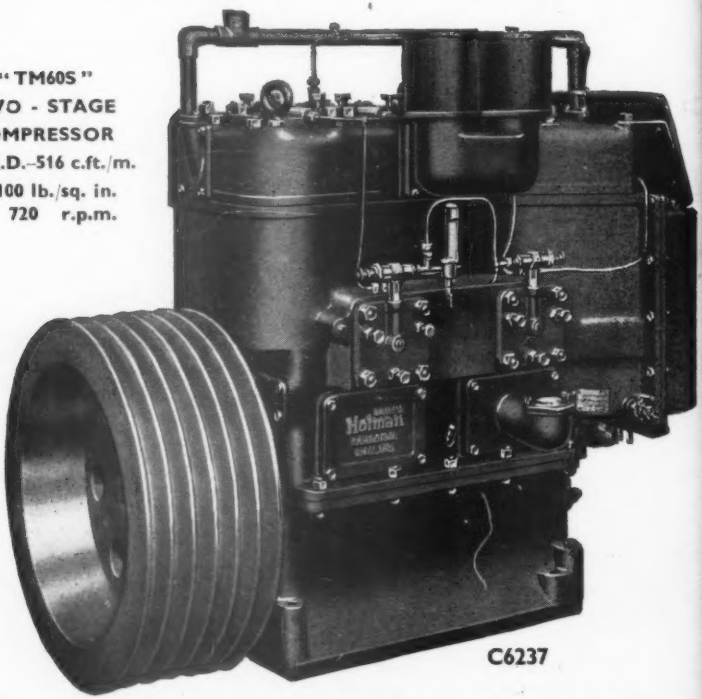

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